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Intensive technologies for the cultivation of winter crops in various edaphic conditions

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ABSTRACT

Currently, in modern world science, a large experimental material has been accumulated to search for new forms of nitrogen nutrition of plants and increase the use of nitrogen fertilizers to obtain sustainable crop yields, which is relevant in modern conditions. A science-based fertilizer system should ensure not only the production of planned crops at the lowest cost per unit of production, but also a systematic increase in soil fertility. The purpose of the study was to scientifically substantiate, develop and introduce into the production of agricultural techniques to increase the yield of grain and leguminous crops cultivated on irrigated lands of the North-Western Caspian Sea, which dropped out of active agricultural turnover. The field study was developed on the basis of existing zonal recommendations, complementing them with options for studied agro-receptions. Laying and conducting multifactorial field experiments in various edaphic conditions by the method of split divides was carried out in accordance with the method of B.A. Dospekhov, Fundamentals of Scientific Research in Agronomy. In order to increase the productivity of irrigated land removed from active agricultural turnover, an environmentally sound land use orientation should be envisaged, while maintaining high agricultural productivity.

Keywords: Wheat, Triticale, Fertilizers, Yield, Factor.

Tecnologias intensivas para cultivo de culturas de inverno em diversas condições edáficas

RESUMO

Atualmente, na ciência do mundo moderno, um grande volume de material experimental foi acumulado para buscar novas formas de adubação nitrogenada das plantas e aumentar o uso de fertilizantes nitrogenados para obter rendimentos agrícolas sustentáveis, o que é relevante nas condições ambientais atuais. Um sistema de adubação base científica deve garantir não apenas a produção de safras planejadas ao menor custo por unidade de produção, mas também um aumento sistemático da fertilidade do solo. O objetivo do estudo foi fundamentar cientificamente, desenvolver e introduzir na produção agrícola técnicas para aumentar o rendimento das culturas de grãos e leguminosas cultivadas em terras irrigadas do Noroeste do Mar Cáspio, que saíram do volume de negócios agrícola ativo. O estudo de campo foi desenvolvido com base nas recomendações dos zoneamentos agrícolas existentes, complementando-as com opções de agro-recepções estudadas. Colocação e realização de experimentos de campo multifatoriais em várias condições edáficas pelo método de divisão foi realizado de acordo com o método de B.A. Dospekhov, Fundamentals of Scientific Research in Agronomy. A fim de aumentar a produtividade das terras irrigadas que saíram do volume de negócios agrícola ativo, deve ser considerada uma orientação de uso da terra ambientalmente correta, mantendo simultaneamente uma elevada produtividade agrícola.

Palavras-chave: Trigo, Triticale, Fertilizantes, Rendimento, Fator.

1. Introduction

In world agriculture today, a large number of agricultural lands are unclaimed and are becoming unused (Borisenko, 2014; Rylov and Bayunov, 2019; Yin et al., 2019; Palšová et al., 2019; Nakvasina et al., 2019; Babajanov and Inamov, 2020; Bochkarev et al., 2020; Merzlova, 2020; Shevchenko et al., 2020; Vdovenko et al., 2020; Chupina et al., 2020; Buletsa, 2020; Prishchepov, 2020; Xie et al., 2020).

So, for example, crop production industries in Russia are mainly limited to areas of risky agriculture with insufficient and unstable humidification, with often repeated droughts and dry animals, which is accompanied by a sharp decrease in yields and gross harvest of crops. A comprehensive analysis of the land resources of the Russian Federation revealed very disappointing results of the general state of arable land.

According to official data, currently in Russia 30 to 40 million hectares of arable land are withdrawn from agricultural turnover and are not used. Almost all of it is subject to various types of erosion and degradation. The current situation in land reclamation is aimed at putting into operation land reclamation and unused to maintain soil fertility. (Kochurov and Ivanov, 2005; Armor, 2011). These territories include the Kalmyk-Astrakhan rice and irrigation system, based on the use of high doses of mineral fertilizers and plant protection products in rice cultivation.

Until the mid-80s, the total area of engineering rice systems in the Sarpinsky lowland totaled more than 18 thousand hectares of which more than 8 thousand hectares were occupied under rice crops.

The largest indicators for the areas occupied by grain crops are 8.1.... 8.3 thousand hectares and gross grain collections 26.3.... 28.7 thousand tons were achieved in 1985... 1990.

The use of zonal technologies was carried out in violation of the relevant agricultural techniques and non-compliance with crop rotation, which led to a significant reduction in sown areas, a decrease in land productivity. At the same time, many thousands of hectares were unclaimed and went into the category of fallow, or, completely removed from the active agricultural turnover of land.

On the basis of the above, the role of research on agricultural land withdrawn from active circulation is increasing, as well as the development of measures to identify and eliminate the consequences of negative processes. All this served as the basis for the search for alternative ways to increase crop yields, as well as changing the economic orientation of irrigated land of arid territories withdrawn from active circulation. Studies in these areas were carried out in soil and climatic conditions of the North-Western Caspian Sea. Winter crops were studied as research objects: winter wheat and winter triticale. Winter crops are important because they produce higher grain yields than spring crops. They develop better than spring ones by using a spring supply of moisture and nutrients (Hanley and Ridgman, 1978; Green and Ivins, 1985; Milivojević et al., 2018; Rajnincová et al., 2019; Malkanduyev et al., 2020; Tsenov et al., 2020).

The subject of research were checks of the rice system of the engineering type, withdrawn from the active agricultural turnover of the Kalmyk-Astrakhan rice and irrigation system, on the territory of the Chernoyarsky and Enotaevsky districts in the conditions of the Astrakhan region. The effectiveness of using modern agro-ecological techniques for cultivating crops on lands withdrawn from active agricultural turnover was studied by laying field experiments. Pilot sites were laid down taking into account the possibility to conduct effective monitoring studies in various edaphic conditions of the study areas.

The basis for field research was the principle of zoning regions of the Astrakhan region according to their specialization in the cultivation of grain and fodder crops, where light chestnut solonetzic and brown semi-desert soils are more represented in their diversity. The main objective of the research was to develop elements of agricultural technology for growing winter crops to obtain stable and high yields under irrigation conditions.

2. Material and Methods

Experiments with various varieties (factor A) of winter wheat Tarasovskaya rosinka, Don-93, Yermak and varieties of winter triticale Valentin and Bard were laid in 3 times repetition by the method of split dividers. The experimental part of the research was carried out from in the conditions of the Nikolskaya rice irrigation system of the Enotaevsky district and the Chernoyarsky irrigation system of the Astrakhan region (Figure 1). On the pilot field, before laying and conducting studies, equalization crops were carried out using spring barley.

Figure 1. Rice system check withdrawn from agricultural turnover

Two three-factor field trials on winter wheat and winter triticale involved the study of the effects of the mineral feeding regime (factor B) control; the main fertilizer for low background $N_{32}P_{32}K_{32}$, as well as average background $N_{64}P_{64}K_{64}$ and increased background - $N_{96}P_{96}K_{96}$. Against the background of the introduction of regulated levels of mineral fertilizers, the effectiveness of three standards of seed sowing from 4.0, 4.5 to 5.0 million parts/ha (factor C) was studied. The area occupied by experience was 10.08 ha. The area of one plot is 560.0 m^2. The repetition of the experience is three-factor. The objects of research were: winter triticale of the Bard, Valentin variety; winter wheat varieties: Tarasovskaya Rosinka, Don-93, Ermak.

The soil on the experimental site №. 1 (Chernoyarsky district) is a light chestnut subtype solonetzic (hereinafter referred to as light chestnut soil), characterized by medium-carbon with a low-power humus horizon (0.2... 0.25 m) and low humus content 1.1% in the arable layer. Cationic exchange capacity - 10.3... 11.2 milligram equivalent /100g. The density of soil for the calculated layers of 0.7 m is 1.36 t m^{-3}, the lowest moisture intensity is 28... 30% mass of dry soil. Calcium prevails in the composition of absorbed bases. Within the humus horizon, it accounts for 60.2% of the amount of absorbed bases. The density of the upper arable layer is 1.42 t m^{-3}, the density of the solid phase is 2.57 wells - 44.8%. Mobile phosphorus (P_2O_5) - 65mg kg^{-1}; mobile potassium (K_2O) - 340 mg kg^{-1}; alkaline hydrolyzable nitrogen (N) - 86.7 mg kg^{-1}. Alkaline soil reaction -7.2. The soils of the test site contain very few water soluble salts throughout the profile.

The soil on experimental site №. 2 (Enotaevsky district) is brown semi-desert. In terms of granulometric composition, it is mainly light (soup). Soils also have a small (10... 15 cm) power of the humus horizon, humus content - 1... 1.3% and cationic exchange capacity - 15.0-20.2 mg-eq/100 g. The composition of exchange cations is dominated by calcium, the content of exchange sodium in the upper horizons is 0.1-1.5% of the sum of exchange bases. Mobile phosphorus (P_2O_5) - 43.9 mg/kg; potassium exchange (K_2O) - 366.0 mg/kg; alkaline hydrolyzable nitrogen (N) - 62.8 mg/kg. The density of the upper arable layer is 1.40 t m^{-3}, the density of the solid phase is 2.61, and the well is 45.7%. Alkaline soil reaction - 8.0. Easily soluble salts are found at a depth of 1.0... 1.5 m and higher within the first meter from the surface.

Agricultural techniques for the cultivation of winter cereals in the field study were developed on the basis of existing zonal recommendations, supplemented by options for the studied agricultural admissions. The laying and carrying out of multifactorial field experiments in various edaphic conditions by the method of split divides was carried out in accordance with the method (Moiseichenko et al, 1996).

On the experimental field, pure pairs were discarded by a tractor MTZ-1021 + BDT-3 to a depth of 0.08... 0.10 m. The differentiated application of mineral fertilizers was calculated for the planned yield of winter grain crops 4.5... 5.0 t/ha, taking into account the content of food elements in the experimental areas. Mineral fertilizers were introduced before sowing, and part of nitrogen fertilizer (N_{30}) with early autumn feeding (on frozen soil) MTZ-1021 + FLN -0.8. Pre-breeding cultivation was carried out to a depth of 0.05... 0.06 m MTZ-1021 + KPS-5.

Sowing of grain crops was carried out MTZ-1021 + S3 3.6. Depth of seed sealing 0.04... 0.05 m. In experiments, in irrigation conditions, irrigation was carried out in cash in checks. In total, 3 watering was carried out (moisture charging -1000 m^3 ha^{-1} + 2 vegetation watering 1600 m^3 ha^{-1}). The irrigation norm was - 4200 m^3 ha^{-1}. The method of watering winter crops was carried out - by the method of flooding according to the Krasnodar type. Studies were carried out in a system of grain-steam-feed crop rotation with a short rotation, consisting of: pure steamy wheat/winter triticale. The crop was harvested by direct harvesting with a combine SK-5.

3. Results and Discussion

The yield of various crops, as is known, largely depends on soil and climatic conditions, as well as on agrotechnological techniques and methods of cultivation, some of which are regulated, and others depend on the characteristics of this soil-climatic zone. Increasing food grain production is now one of the most important tasks of the agro-industrial series of countries. One of the promising areas of its solution is the justification and development of regional organizational and technological systems for obtaining sustainable yields and high-quality grain (Furmanetc et al., 2022; Vafin et al., 2023; Tkachuk, 2022; Vojnov et al., 2023).

The introduction of diammophosk $N_{10}P_{26}K_{26}$ + N_{34} for feeding into the phase of the beginning of feeding + N_{46} the beginning of the emergence of plant seedlings into the tube for pre-sowing treatment for growing plants of winter barley of winter barley and extra-root feeding with urea in a dose of N_8 + microfertilization Ecolist from the calculation of 4.0 l/ha contributed to the possibility of obtaining a grain harvest of winter barley of the Atlant Mironovsky variety at the level of 6.81 t/ha, Paso variety. - 7.29 t/ha, which is more for control areas without application of fertilizers by 4.97-5.23 t/ha (Shkatula and Barsky, 2021).

Similar work provided for the introduction of (FYM); FYM + P; FYM + K; FYM + PK; FYM + N1; FYM + N2; FYM + N1PK; FYM + N2PK и FYM + N3PK, and the highest grain yields were recorded during processing FYM + P и FYM + N_3PK (8,9 т/га). The highest yields of straw were recorded during processing FYM + N_3PK (6,52 т/га) (Holík et al., 2018).

In our studies, according to the results given in Table 1, two highly productive options with a yield of 4.8... 4.9 t/ha in winter triticale of the Bard variety were definitely distinguished: with a mineral nutrition regime of $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$ and a seeding rate of 4.0 million units/ha. It should be noted that the studies conducted on winter triticale of the Valentine variety revealed the same pattern as for the Bard variety. It should be noted that with an increased regime of mineral nutrition, the indicators of the elements of the crop structure decreased, and therefore the yield of the studied crop. Highly productive options in the study of the cultivation of winter triticale of the Valentine variety were at the level of mineral nutrition of $N_{32}P_{32}K_{32}$, $N_{64}P_{64}K_{64}$ and $N_{64}P_{64}K_{64}$and the sowing rate of 4.5 million parts/ha (Table 1).

Analyzing the yields of triticale Bard, on average, over the years of research, it was found that the maximum data were obtained on the variant $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$ at a seeding rate of 4.0 and 4.5 million parts/ha. Yields on variants ranged from 4.8 to 4.9 t/ha. Maximum yield indicators from 5.1 to 5.8 t/ha for this triticale variety were noted only study on the variant with the regime of mineral fertilizers application $N_{32}P_{32}K_{32}$ with all sowing standards.

Table 1. Yield of winter cereals, depending on the level of mineral nutrition and sowing rate in conditions of brown semi-desert soil

Option	Norma sowing, million units/ha	Number of productive stems before harvesting parts /m^2	Grain weight with 1 spike, g.	Biological yield, t/ha
Winter triticale of Bard variety				
Control without fertilizers	4.0 (к)	450.0	0.75	3.4
	4.5	451.0	0.78	3.5
	5.0	443.0	0.87	3.9
$N_{32}P_{32}K_{32}$	4.0	447.0	1.07	4.8
	4.5	447.0	1.07	4.8
	5.0	452.0	1.03	4.7
$N_{64}P_{64}K_{64}$	4.0	451.0	1.08	4.9
	4.5	451.0	1.04	4.7
	5.0	447.0	0.98	4.4
$N_{96}P_{96}K_{96}$	4.0	441.0	1.03	4.6
	4.5	441.0	0.99	4.4
	5.0	440.0	0.95	4.2
Winter triticale of Valentin variety				
Control without fertilizers	4.0 (к)	447.0	0.74	3.3
	4.5	450.0	0.76	3.4
	5.0	449.0	0.98	4.4
$N_{32}P_{32}K_{32}$	4.0	450.0	1.06	4.8
	4.5	452.0	1.10	5.0
	5.0	453.0	1.06	4.8
$N_{64}P_{64}K_{64}$	4.0	456.0	1.09	5.0
	4.5	451.0	1.11	5.0
	5.0	453.0	1.10	5.0
$N_{96}P_{96}K_{96}$	4.0	454.0	1.08	4.9
	4.5	447.0	1.14	5.1
	5.0	44.0	1.10	4.9
SSD_{05} (A)				0.16
SSD_{05} (B)				0.16
SSD_{05} (C)				0.16
SSD_{05} (AB)				0.27
SSD_{05} (AC)				0.27
SSD_{05} (BC)				0.27
SSD_{05} (ABC)				0.17

Factor A – grade; factor B - mineral nutrition mode; factor C - sowing rate; SSD_{05} - smallest significant difference.

In winter wheat of Don-93 variety, options with increased introduction of mineral fertilizers turned out to be highly productive $N_{64}P_{64}K_{64}$ and $N_{96}P_{96}K_{96}$ for all, the sowing rate 4.0... 5.0 million parts/ha. As the obtained data on winter wheat of Yermak variety showed, the best results on the elements of the crop structure were found on variants with a sowing rate of 4.5 million parts/ha and mineral fertilizer regimes $N_{32}P_{32}K_{32}$, $N_{64}P_{64}K_{64}$ and $N_{96}P_{96}K_{96}$.

Considering the productivity of winter wheat of the Tarasovskaya rosinka variety for a long period of study, it should be noted that the most productive option was the option with a mineral nutrition regime $N_{64}P_{64}K_{64}$ and seeding standards of 4.0, 4.5 and 5.0 million psi/ha. Yields at these standards ranged from 4.4 to 4.7 t/ha. The results of the studies obtained during the cultivation of winter wheat of the Yermak variety revealed the best options for all the factors studied, both in terms of mineral fertilizer application regimes and in terms of sowing standards from 4.0 million parts/ha, 4.5 million million parts/ha and up to 5.0 million parts/ha - $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64.}$ The agricultural techniques studied in the study had a noticeable impact on the productivity of winter wheat varieties Yermak and Don-93.

As seed sowing rates increased from 4.0 to 5.0 million parts/ha, respectively, the yield increased. In crops with a sowing rate of 4.0 to 4.5 million parts/ha, the yield of various varieties of winter wheat exceeded the previous version, on average, by 0.2 t/ha, but was inferior to the subsequent by 0.3 t/ha. It should also be noted that with an increased level of mineral nutrition $N_{96}P_{96}K_{96}$ and sowing rate of seeds up to 5.0 million parts/ha, there is a decrease in yield compared to the optimal rate of 4.5 million parts/ha during the mineral feeding regime $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$, which was economically unjustified.

The decrease in the yield of winter crops with an increased sowing rate of 5.0 million parts/ha was due to thickening of crops, which led to plant oppression and deterioration of development conditions in crops. The analysis of the indicators of the elements of the crop structure in the studies conducted on the application of various regimes of introduced mineral fertilizers and sowing standards reflected a certain pattern. Thus, the productive bush decreased with an increased seeding rate (5.0 million parts/ha) and increased with a decrease in the seeding rate to 4.5 and 4.0 million parts/ha of plants per unit area.

Mineral fertilizers had a decisive influence on the formation of indicators of elements of the crop structure, both with the main and fractional introduction of them (i.e. before sowing in autumn and spring on frozen soil). It should be noted that the formation of the main indicators of the crop structure was influenced to a greater extent by various introduced mineral fertilizers and seed sowing standards. The most pronounced effect in the cultivation of all the listed crops was the rate of sowing 4.5 million parts/ha and the regime of mineral nutrition $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$for all crops included in the study (Table 2).

So, for example, the winter triticale of the Bard and Valentin varieties showed itself most responsibly in light chestnut soil conditions on versions with a mineral nutrition regime $N_{64}P_{64}K_{64}$ and a seeding norm of 4.5 and 5.0 million parts/ha. Yields with such indicators of elements of the crop structure also varied significantly according to research options. Most effectively, plants of winter triticale of the Valentine variety responded to the introduction of various mineral nutrition regimes. Yield indicators exceeded the value of 5.0 t/ha on the average $N_{32}P_{32}K_{32}$ and increased $N_{64}P_{64}K_{64}$ and $N_{96}P_{96}K_{96}$ modes of mineral nutrition at the sowing rate from 4.0 to 5.0 million parts/ha.

The yield on the winter triticale variety of the Bard variety has changed significantly according to options. The first year after laying the experience was significantly different in all indicators, and exceeded all subsequent years of research. Maximum values were achieved at an optimal seeding rate of 4.5 million pcs/ha and mineral feeding modes $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$ from 4.7 to 4.8 tons/ha (Table 3).

The values of the control variant differed significantly from the indicators with the introduction of mineral fertilizers. The increase in all variants was from 1.0 to 1.5 t/ha. As mentioned earlier, the productivity of winter crops was directly dependent on the regime of mineral fertilizers and sowing standards. High yields, during the period of studies in winter wheat of Don-93 variety were observed in two modes of mineral nutrition $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$ with a sowing rate of 4.5 million parts/ha, with a yield of 4.6 to 4.7 t/ha (Table 4).

Experimental data obtained from the studies were processed using three-factor variance analysis in Excel, which is part of the Microsoft Office 2010 installation package. Based on the results of the dispersion analysis, SSD $_{05}$ was calculated. As a result of the calculations, it was found that factor A (grades and hybrid) effects of the mineral feeding regime (main fertilizer for low background $N_{32}P_{32}K_{32}$, as well as average background $N_{64}P_{64}K_{64}$ and elevated background - $N_{96}P_{96}K_{96}$) - Factor B, three sowing rates from 4.0, 4.5 to 5.0 million parts/ha, Factor C had a significant impact on the yield of winter cereals F (actual) turned out to be ≥ F (theoretical). The interaction of the three factors also had a significant impact on yields. F (actual) turned out to be ≥ F (theoretical).

Table 2. Yield of winter cereals, depending on the level of mineral nutrition and sowing rate in conditions of brown semi-desert soil

Option	Norma sowing, million units/ha	Number of productive stems before harvesting parts /m^2	Grain weight with 1 spike, g.	Biological yield, t/ha
Winter wheat of Tarasovskaya rosinka variety				
Control without fertilizers	4.0 (к)	443.0	0.76	3.4
	4.5	444.0	0.68	3.0
	5.0	451.0	0.82	3.7
$N_{32}P_{32}K_{32}$	4.0	431.0	1.04	4.5
	4.5	445.0	0.94	4.2
	5.0	434.0	1.01	4.4
$N_{64}P_{64}K_{64}$	4.0	493.0	0.99	4.4
	4.5	436.0	1.06	4.6
	5.0	445.0	1.03	4.6
$N_{96}P_{96}K_{96}$	4.0	438.0	0.98	4.3
	4.5	441.0	1.02	4.5
	5.0	432.0	1.02	4.4
Winter wheat of Don-93 grade				
Control without fertilizers	4.0 (к)	440.0	0.77	3,4
	4.5	443.0	0.84	3,6
	5.0	442.0	0.84	3,7
$N_{32}P_{32}K_{32}$	4.0	443.0	1.04	4,6
	4.5	435.0	1.10	4,8
	5.0	436.0	1.03	4,5
$N_{64}P_{64}K_{64}$	4.0	448.0	1.05	4,7
	4.5	450.0	1.04	4,7
	5.0	436.0	1.01	4,4
$N_{96}P_{96}K_{96}$	4.0	447,0	1.01	4,5
	4.5	440,0	1.00	4,4
	5.0	443,0	0.93	4,1
Winter wheat Ermak				
Control without fertilizers	4.0 (к)	513.0	0.64	3.3
	4.5	448.0	0.67	3.0
	5.0	461.0	0.85	3.9
$N_{32}P_{32}K_{32}$	4.0	442.0	0.96	4.3
	4.5	457.0	0.98	4.5
	5.0	450.0	1.02	4.6
$N_{64}P_{64}K_{64}$	4.0	447.0	0.98	4.4
	4.5	471.0	0.93	4.4
	5.0	441.0	1.00	4.4
$N_{96}P_{96}K_{96}$	4.0	432.0	1.04	4.5
	4.5	441.0	1.00	4.4
	5.0	432.0	1.00	4.3
SSD_{05} (A)				0.10
SSD_{05} (B)				0.10
SSD_{05} (C)				0.10
SSD_{05} (AB)				0.20
SSD_{05} (AC)				0.20
SSD_{05} (BC)				0.17
SSD_{05} (ABC)				0.11

Factor A - grade, factor B - mineral nutrition mode, factor C- sowing rate

Table 3. Yield of winter cereals, depending on the level of mineral nutrition and sowing rate in light chestnut soil

Option	Norma sowing,	Number of productive	Grain weight with 1	Biological yield, t/ha
Winter triticale of Bard variety				
Control without fertilizers	4.0 (к)	448.0	0.73	3.2
	4.5	466.0	0.72	3.4
	5.0	447.0	0.83	3.7
$N_{32}P_{32}K_{32}$	4.0	444.0	1.05	4.7
	4.5	451.0	1.04	4.7
	5.0	451.0	0.99	4.5
$N_{64}P_{64}K_{64}$	4.0	449.0	1.07	4.7
	4.5	448.0	1.01	4.8
	5.0	449.0	0.94	4.2
$N_{96}P_{96}K_{96}$	4.0	443.0	0.99	4.4
	4.5	441.0	0.97	4.3
	5.0	440.0	0.93	4.,1
Winter triticale of Valentin variety				
Control without fertilizers	4.0 (к)	445.0	0.70	3.1
	4.5	451.0	0.73	3.3
	5.0	448.0	0.94	4.2
$N_{32}P_{32}K_{32}$	4.0	451.0	1.04	4.7
	4.5	450.0	1.08	4.9
	5.0	444.0	1.03	4.6
$N_{64}P_{64}K_{64}$	4.0	453.0	1.08	4.9
	4.5	451.0	1.08	4.9
	5.0	448.0	1.07	4.8
$N_{96}P_{96}K_{96}$	4.0	441.0	1.06	4.7
	4.5	444.0	1.12	5.0
	5.0	440.0	1.07	4.7
SSD_{05} (A)				0.15
SSD_{05} (B)				0.15
SSD_{05} (C)				0.17
SSD_{05} (AB)				0.30
SSD_{05} (AC)				0.30
SSD_{05} (BC)				0.26
SSD_{05} (ABC)				0.15

Factor A - grade, factor B - mineral nutrition mode, factor C- sowing rate, SSD_{05} - smallest significant difference.

Based on the statistical analysis of experimental data, regression relationships were obtained describing the pattern of change in the grain yield of winter cereals from the level of mineral nutrition and the sowing rate under conditions of brown semi-desert and light chestnut soil:

$$Y=a+b(NPK)+c(SR)+d(NPK)^2+e(SR)^2+f(NPK)(SR) \quad \text{(type 1)}$$

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$$Y=a+b(NPK)+c(NPK)^2+ d(NPK)^3+e(SR)+ f(SR)^2 \quad \text{(type 2)}$$

Where:

NPK is the dose of fertilizer application for the main elements of mineral nutrition, kgd.v./ha; SR is the sowing rate, million cem/ha; Y is yield, t/ha. The dependencies of the two types (forms) and their parameters are shown in Table 5.

For example, for winter triticale of the Valentin variety cultivated under conditions of brown semi-desert soil, the equation of dependence was as follows:

$$Y=1.8+0.087(NPK)+0.32(SR)+ (-0.00029)(NPK)^2+0.05(SR)^2+(-0.01)(NPK)(SR) \quad \text{(type 1)}$$

The magnitude of the coefficient of determination equal to the square of the correlation was R^2 = 0.88 (Figure 2). For winter wheat of the Tarasovskaya dew variety cultivated under light chestnut soil conditions, the equation of dependence was as follows:

$$Y =2.75+0.052(NPK) + (-0.0007)(NPK)^2 + 2.88e-0.6(NPK)^3 + 0.1(SR) + 0(SR)^2 \quad \text{(type 2)}$$

The magnitude of the coefficient of determination equal to the square of the correlation was R^2 = 0.91. (Figure 3).

Table 4. Yield of winter cereals, depending on the level of mineral nutrition and sowing rate in light chestnut soil

Option	Norma sowing, million units/ha	Number of productive stems before harvesting parts /m^2	Grain weight with 1 spike, g.	Biological yield, t/ha
Winter wheat of Tarasovskaya rosinka variety				
Control without fertilizers	4.0 (к)	447.0	0.72	3.2
	4.5	448.0	0.65	2.9
	5.0	456.0	0.77	3.5
$N_{32}P_{32}K_{32}$	4.0	435.0	0.99	4.3
	4.5	450.0	0.93	4.2
	5.0	438.0	0.95	4.2
$N_{64}P_{64}K_{64}$	4.0	447.0	0.96	4.3
	4.5	440.0	1.02	4.5
	5.0	454.0	0.97	4.4
$N_{96}P_{96}K_{96}$	4.0	442.0	0.93	4.1
	4.5	446.0	1.01	4.5
	5.0	436.,0	0.96	4.2
Winter wheat of Don-93 grade				
Control without fertilizers	4.0 (к)	445.0	0.72	3.2
	4.5	471.0	0.74	3.5
	5.0	452.0	0.79	3.6
$N_{32}P_{32}K_{32}$	4.0	449.,0	0.98	4.4
	4.5	444.0	1.05	4.7
	5.0	453.0	0.97	4.4
$N_{64}P_{64}K_{64}$	4.0	465.0	0.97	4.5
	4.5	463.0	0.99	4.6
	5.0	458.0	0.92	4.2
$N_{96}P_{96}K_{96}$	4.0	469.0	0.92	4.3
	4.5	448.0	0.96	4.3
	5.0	449.0	0.87	3.9
Winter wheat Ermak				
Control without fertilizers	4.0 (к)	487.0	0.64	3.1
	4.5	456.0	0.66	3.0
	5.0	474.0	0.78	3.7
$N_{32}P_{32}K_{32}$	4.0	455.0	0.90	4.1
	4.5	470.0	0.94	4.4
	5.0	472.0	0.93	4.4
$N_{64}P_{64}K_{64}$	4.0	469.0	0.89	4.2
	4.5	500.0	0.88	4.4
	5.0	463.0	0.93	4.3
$N_{96}P_{96}K_{96}$	4.0	453.0	0.95	4.3
	4.5	454.0	0.95	4.3
	5.0	457.0	0.89	4.1
SSD_{05} (A)				0.15
SSD_{05} (B)				0.15
SSD_{05} (C)				0.15
SSD_{05} (AB)				0.26
SSD_{05} (AC)				0.26
SSD_{05} (BC)				0.26
SSD_{05} (ABC)				0.16

Factor A - grade, factor B - mineral nutrition mode, factor C- sowing rate

Table 5. The dependence of winter crop yields on the level of mineral nutrition and sowing standards in various edaphic conditions

Soil	Culture, variety	The form of the equation	a	b	c	d	e	f	R^2
Brown semi-desert soil	tritikat	type 1	3.13	0.08	-0.11	-0.00035	-0.05	-0.0097	0.90
	tritikat	type 1	1.28	0.087	0.32	-0.00029	0.05	-0.01	0.88
	wheat variety Trasovskaya dew	type 2	13.8	0.05	-0.000671	2.71e-0,6	-4.8	0.55	0.91
	wheat variety Don-93	type 2	-6.91	0.059	-0.00096	4.41e-06	4.82	-0.55	0.91
	wheat variety Ermak	type 1	11.8	0.072	-4.37	-0.00026	0.55	-0.008	0.91
Light chestnut soil	tritikat	type 1	-6.81	0.081	4.33	-0.00036	-0.45	-0.008	0.89
	tritikat	type 1	-4.68	0.088	2.97	-0.0003	-0.25	-0.01	0.88
	wheat variety Trasovskaya dew	type 2	2.75	0.052	-0.0007	2.,88e-06	0.1	0	0.91
	wheat variety Don-93	type 1	0.70	0.076	7.98	0.00032	-0.85	-0.0084	0.94
	wheat variety Ermak	type 2	0.66	0.071	0.59	-0.00027	-8.51e-6	-0.0081	0.94

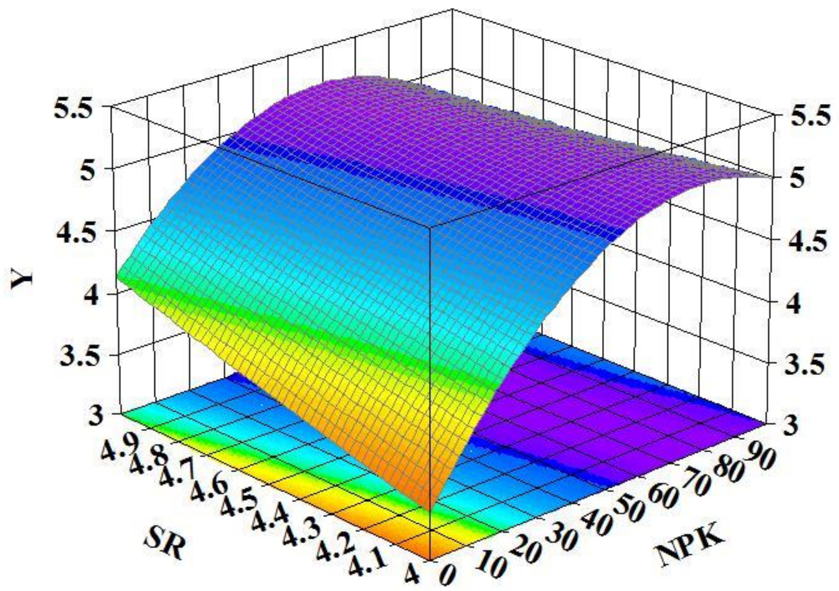

Figure 2. Dependence of grain yield of winter triticale of Valentin variety on the level of mineral nutrition and sowing norm in conditions of brown semi-desert soil. (Y - seed rate; SR - productivity**)**

4. Conclusions

In light chestnut solonets and brown semi-desert bees of the Astrakhan region, as well as in other arid regions similar in climatic conditions, the cultivation of winter cereals in irrigation conditions requires 3 watering: moisture charging of 1000 m^3/ha + 2 vegetation watering of 1600 m^3/ha of checks of the rice system of the engineering type, and calculated levels of mineral nutrition $N_{32}P_{32}K_{32}$ and $N_{64}P_{64}K_{64}$ at a seeding rate of 4.5 million parts/ha.

It is recommended to use the following set of crops (winter triticale of Valentin variety and winter wheat of Don-93 variety), taking into account the pre-fuel threshold of moisture 70% lowest water capacity in the flowering phase, within the limits of 70…75% lowest water capacity in the dairy ripeness phase, and by the beginning of the technical ripeness phase 60... 65% lowest water capacity, which ensured the output of commercial products over 4.5 t/ha. The developed and proposed agricultural technology fundamentally changes the economic orientation of the checks of the rice system of the engineering type.

Authors' Contribution

The only author of this manuscript made a direct contribution to the development of a scientific study, to the staging and conduct of a field experiment. He carried out a lot of work in the analysis of the received materials and in the direct writing of this manuscript.

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