AGROTECHNOLOGICAL METHODS OF GRAIN CROP CULTIVATION WITH NITROGEN-FIXING MICROORGANISM-CONTAINING SEED DRESSING

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Abstract: In crop growing, crops are closely connected with the environment. The maximum yield of high quality can be obtained only in case of a favorable combination of all the factors of plants development and agrotechnological approaches. However, the deficiency of one of the microelements required for the plant growing inhibits its development and the lack – leads to its death. A demand in high yield and ecologically clean production, improvement in the qualitative parameters of the final product, cleaning the soil from chemical substances and heavy metals provoked an increased interest in the development of ecologically-oriented systems of farming that are based on a steady replacement of some agricultural chemicals with biological products, primarily, microbiological drugs. Microbiological drugs positively influence the accumulation of the plant biomass during the vegetation. The effectiveness of inoculation depends on the varietal peculiarities of crops, the level of soil fertility, weather conditions, and strains that are contained in the drugs. The study lasted from 2011 to 2014 at the facilities of the Caspian Sea Agrarian Federal Research Center of RAS (CSAFRCRAS). The aim of the present study was to evaluate the influence of new nitrogen-fixing microbiological drugs Agrophil, Mizorin, Flavobacterin, and Rhizoagrin-204 on the yield of spring crops on light-chestnut alkaline soil in Astrakhan Oblast. Agrotechnological measures included generally accepted agrotechnological methods according to the region-based recommendations. The authors performed field trials, observations, and measurements using generally accepted methods. The present article describes the results of the studies on the influence of microbiological drugs on the productivity of spring crops on light-chestnut alkaline soil. The authors specified the most efficient variants of cultivation of the studied crops. The study results showed that the best parameters of yield structure and biological yield were obtained in the variants that involved Flavobacterin, Mizorin, and Agrophil. Nitrogen-fixing microbiological seed dressing showed its growth-stimulation activity. The maximum yield increase that ranged from + 0.5 to +1.2 t/ha in comparison with the control variant was obtained in the variants that involved Flavobacterin, Mizorin, and Agrophil. Biological yield in spring wheat was 4.0 t/ha, and in spring barley – 4.8-4.9 t/ha. **Keywords**: strains, irrigation, consumptive water use, water-use ratio, yield structure, yield increase

1. Introduction.

A demand in high yield and ecologically clean production, improvement in the qualitative parameters of the final product, cleaning the soil from chemical substances and heavy metals provoked an increased interest in the development of ecologically-oriented systems of farming that are based on a steady replacement of some agricultural chemicals with biological products, primarily, microbiological drugs [13-22].

One of the directions in biopharming is the application of microbiological drugs that contain nitrogen-fixing microorganisms. Application of nitrogen-fixing capacity of soil bacteria and its optimization due to the soil nitrogen balance in the agroecosystems with allow the farmers to solve many issues of the resistance in modern farming [1; 2; 3; 8; 10].

Microfertilizer dressing accelerates germination, increases vegetative mass and productivity, and improves the quality of grain and its resistance to diseases and pests. Bacterial drugs can influence plants at different stages of growth and development. However, the best effect is observed after a pre-drilling seed dressing [6; 11; 12].

The study of the effectiveness of bacterial preparations and their application on spring crops in the conditions of the arid climate of the Astrakhan region and similar climatic regions is relevant had has a scientific value.

The aim of the present study is the evaluation of the influence of new biopreparations based on the associative nitrogen-fixing bacteria Agrophil, Mizorin, Flavobacterin, and Rhizoagrin-204 on the yield of spring crops on light chestnut soil of Astrakhan region.

The crop was drilled in the established agroclimatic dates on an irrigated plot. The depth of drilling was 4 cm. Pre-drilling inoculation of seeds with different microbiological products was performed. The inoculant rate per hectare seed rate was 600g. The treated drugs were drilled within 1-2 days in the soil with temperature not less than +5+6 ^{0}C.

2. Materials and Methods

Flavobacterin is based on the strain L №30. 1g of peat biological product contains 5-10 billion bacterial cells of this strain.

This product is a powder-like peat substrate enriched with nutrients with 45-50% moisture content. The peculiarity of the product is in its wide spectrum of action, positive results were obtained for wheat, barley, rye, oats, and rice. The positive effect of the product is determined by the capacity of bacteria to fix molecular nitrogen, stimulate growth, produce phytohormones, improve mineral consumption and water metabolism, and activate other physiological processes in plants.

The seed dressing with this product provides additional 0.3-0.5 t/ha of grain. The inoculant application rate is 600g per seed rate/ha. Flavobacterin is used for seed dressing of winter wheat.

Mizorinн is based on the strain №8. 1g of peat biological product contains 5-10 billion bacterial cells of this strain. This product is a powder-like peat substrate enriched with nutrients with 45-50% moisture content. The high effectiveness of the product is observed in winter rye.

The seed dressing with this product enhances germination, stimulates growth, and increases the resistance of plants to foot rot and other diseases. The inoculant application rate is 600g per seed rate/ha. Mizorin is used in combination with Rhizotrophin to increase the yield and improve the quality of grain (spring wheat).

Agrophil is a pure culture of agrobacterium that is maintained active on a specially prepared peat material carrier. The product is a moist bulk dark substance that is insoluble in water and has a light characteristic odor. 1g of Agrophil contains not less than 1o billion bacterial cells. It can convert unavailable soil phosphorus (up to 30%) into easily absorbed compounds. It improves the seed germination, stimulates the growth and development of crops, enhances the plants' resistance to diseases, improves mineral and water metabolism, and accelerates early ripening. The inoculant application rate is 600g per seed rate/ha.

Rhizoagrin is based on the strain №204. 1g of peat product contains 5-10 billion bacterial cells. The strain develops well in the rhizosphere of wheat. It increases the yield, improves the quality of grain, and protects the crops from diseases (wheat, rye, barley). The seed dressing with this product provides additional 0.3 – 0.7 t/ha of winter and spring wheat, 0.4 – 0.8 t/ha of winter rye, 0.3 – 0.6 t/ha of barley. The content of protein in grain increases by 0.5 – 1.0%. The inoculant application rate is 500g per seed rate/ha. Rhizoagrin is used for pre-drilling seed dressing of rice, winter wheat, rye, and barley.

Agrotechnological measures included generally accepted agrotechnological technological methods according to the region-based recommendations. Agrotechnological measures included generally accepted agrotechnological approaches according to the region-based recommendations. The authors performed field trials, observations, and measurements using generally accepted methods by Dospekhov (1985) and Moiseichenko (1996) [4; 9]:

- Soil moisture measurement at the main phases of crop development was performed on the trial plots. The soil samples were taken from the layer 0.7 m deep every 0.1m in 3 replicates by the Kachinskiy sampler AM-16. The soil moisture was measured in percent to absolutely dry soil by thermostat-weight method (GOST 27548-97) with further recalculation of moisture % to mm of productive moisture layerwise in 1 m of soil.
- Consumptive use of water during the period of vegetation was estimated by the method of water balance by Kostyakov [7];

$$E = m + \mu A \pm \Delta W, \ m^3/ha,$$

where: E – consumptive use of water;
m – irrigation water, m^3/ha;
A – precipitation, m^3/ha;
μ – precipitation utilization coefficient;
±ΔW – the change in the soil moisture reserve during the studied period.

General moisture reserve in the soil at the studied depth was calculated by the formula:

$$W = \gamma \times d \times h,$$

where: W – general water reserve, mm
γ – spoil moisture, in % to absolutely dry soil;
d =1.41 – specific density of soil, g/cm^3;
h = 70 cm – depth.

For the estimation of the reserves of available (productive) moisture in the studied layer, the amount of moisture unavailable for plants was deducted from the total moisture content:

$$W\ t/ha = (\gamma - k) \times d \times h,$$

where: W t/ha – reserves of productive moisture in the soil, mm;
γ – soil moisture, in % to absolutely dry soil;
k – wilting coefficient (wilting moisture content);
d =1.41 – specific density of soil, g/cm^3;
h = 0.80 m – depth.

- Grain yield was accounted by a biological method with further recalculation for 14% moisture and 100% purity.
- The evaluation of the yield structure was performed by the sampling of grain from the 0.25 m^2 trial plots in 4 replicates.
- The content of total nitrogen in plants samples was evaluated by the method of Kjeldahl;
- The content of protein in grain crops (wheat, barley) was calculated by multiplying the percent of content total nitrogen by 5.70 coefficient;

- For the calculation of the amount of nitrogen outflow from the vegetative mass to the grain, the authors used the formula proposed by McNeal et al (1971):

$$CO = \frac{{}_{FL} \qquad {}_{FR}}{N_{FL}} 100,$$

where, CO – completeness of outflow from the vegetative organs to the grain, %;

N_{FL} – amount of nitrogen in the vegetative organs at the phase of flowering, mg/vessel (g/100 plants, kg/ha);

$_{FR}$ – amount of nitrogen in the vegetative organs at the stage of full ripeness, mg/vessel (g/100 plants, kg/ha).

- Nitrogen index (NI) was used to evaluate the capacity of the genotype to the transportation of nitrogen to grain, i.e. in its biological consumption. Nitrogen index was calculated by the formula proposed by Klimashevskiy [5]:

$$NI = \frac{Ng}{Ng + Nveg}\frac{Ng}{Ng + Nveg},$$

where, – amount of nitrogen in grain at the stage of full ripeness, mg/vessel (g/100 plants, kg/ha); – number of nitrogen in all the above the ground mass at the phase of full ripeness, mg/vessel (g/100 plants, kg/ha).

3. Results and Discussion

The studied soil on the trial plot was light chestnut soil with light loamy mechanical composition, which satisfied the requirements of crop growing. The study included the tests on the content of humus and macroelements by the reaction of the soil medium, degree, and type of salinization.

The results of agrochemical study indicated that the soil of the irrigated plot had a low content of humus (1.1%). All the studied area was characterized by a low level of nitrogen for the growth of different vegetables. The weighted mean content of this element on the studied area was 16.8 mg/kg of soil or 57.1 kg/ha. The content of labile phosphorus varied from 17 to 27 mg/kg of soil and its weighed mean content was 20.8 mg/kg of soil or 70.7 kg/ha.

The mean content of exchange potassium varies from 212 to 264 mg/kg of soil and the weighted mean, in general, was 231.2 mg/kg or 786.1 kg/ha.

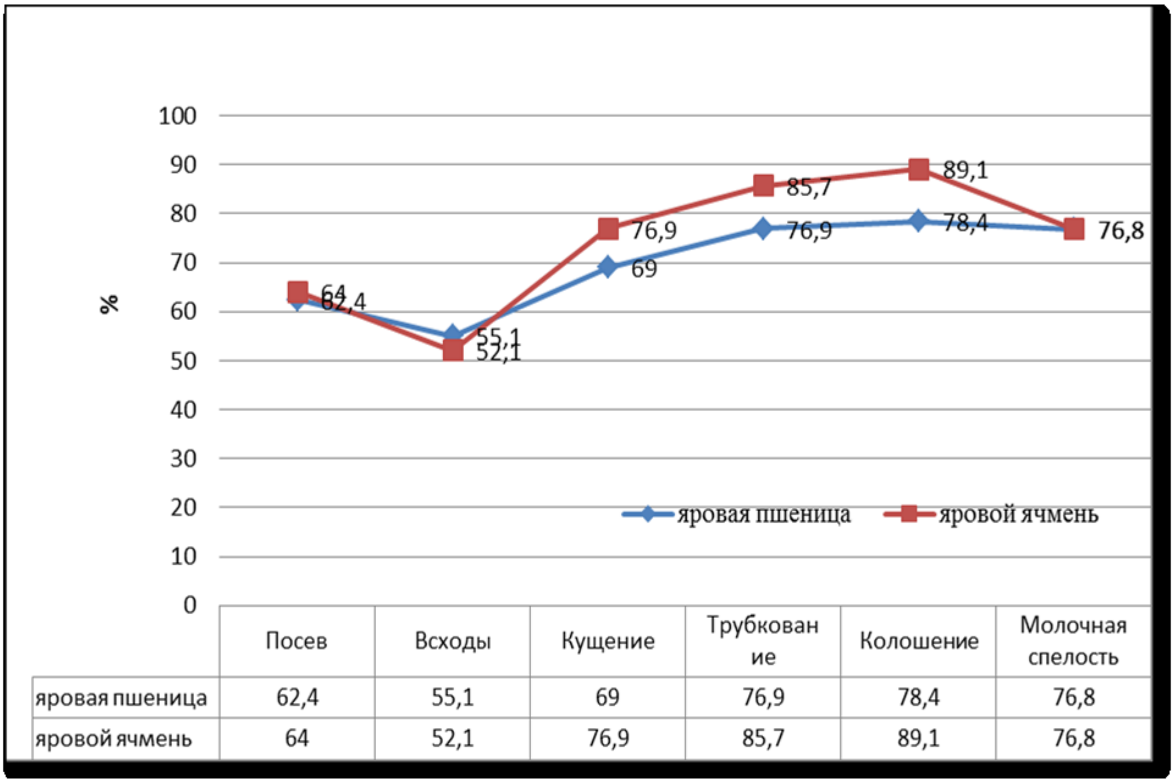
Based on the results of the agrochemical study that provided the data on the level of microelement provision, the authors calculated the total requirement in the elements for the planned yield.

The cultivation of spring wheat Saratovskaya 70 and spring barley Nutans 553 on the light chestnut soil of Lower Povolzhie included generally-accepted agrotechnological techniques: stubble tillage, autumn organic and mineral fertilizers application. The main application of mineral fertilizer included phosphorous-containing substances at the dose of 15-20 kg of active ingredient per hectare (phosphorus) and 10-12 kg/ha (potassium). For the reduction of pathogenic microflora and tillage of stubble and organic fertilizers, deep ploughing was performed. Before the drilling, nitrogen-containing fertilizers were applied during cultivation (1RMG-4 spreader of mineral fertilizer) at the dose of 30-36 kg of active ingredient per hectare.

All the vital processes in the plant can be normal only in the conditions of sufficient water supply. Water is the factor of pants growth and yielding. During the drilling on the light chestnut alkaline soil, the moisture content was 65-70% in a 0-0.7m layer, which provided even germination.

The results of the performed analysis showed that the water input in the general water balance in the studied spring crops was provided by the irrigation during the vegetation (74.3% from the total consumptive water use). The share of precipitations was 54.4 mm or 14.7% of the consumptive water use and the share of moisture obtained from soil was only 11.1% or 41.2 mm (Table 1).

The results of the study performed in 2011-2014 on the spring crops using different microbiological products revealed the following dynamic of the soil moisture. During the drilling, the soil moisture in the soil layers 0.0 – 0.8m was 64.1 – 62.4%, which provided even germination.



	Посев	Всходы	Кущение	Трубкование	Колошение	Молочная спелость
яровая пшеница	62,4	55,1	69	76,9	78,4	76,8
яровой ячмень	64	52,1	76,9	85,7	89,1	76,8

Яровая пшеница – Spring wheat

Яровой ячмень – Spring barley

Посев – Drilling

Всходы – Germination

Кушение – Tillering

Трубкование – Booting

Колошение – Earing

Молочная спелость – Milk ripeness

Figure 1. Dynamics of soil moisture (%) in spring crops, mean for 2011-2014.

Figure 1 shows that during the period of drilling-germination, the moisture content from the norm (%) in spring wheat Saratovskaya 70 varied from 62,4% to 55.1% and in spring barley Nutans 553 – from 64.0 to 52.1%. At the phase of tillering, this parameter was equal to 69.0 – 76.9%, at the phase of booting – 76.9 – 85.7%. In the interphase period of earing-milk ripening, this parameter for spring wheat varied from 76.8 to 78.4% and in spring barley – from 76.8 – 89.1%.

In the dry weather conditions of the Astrakhan Region, it is important to increase the plants' ability of reutilization and balancing of the ratio of the biomass to the grain (Table 2). For grain crops, the nitrogen index varies from 0.36 to 0.70. The higher the index, the better is the genotype response to nitrogen, in particular, its ability to absorb nitrogen from the soil and reutilize endogenous nitrogen during the phase of grain filling.

The analysis of the obtained data by the trial variants showed that out of all the studied variants of pre-drilling seed dressing with microbiological nitrogen-fixing inoculants, the maximum nitrogen outflow was observed in the variants with Flavobacterin, Mizorin, and Rhizoagrin-204. Nitrogen consumption from the soil depended on the yield of spring crops. The higher was the yield and nitrogen content, the higher was the consumption.

Parameter		Control	Flavobacterin	Mizorin	Agrophil	Rhizoagrin-204
Spring wheat, Saratovskaya 70 variety						
Content of N in plants during flowering, %		3.1	3.8	3.9	3.8	4.0
Content of N in plants during full ripeness, %	grain	2.1	2.4	2.3	2.3	2,6
	straw	1.5	1.4	1.7	1.7	1,6
	total	3.6	3.8	4.0	4.0	4,2
N outflow efficiency to grain, %		58.3	63.2	57.5	57.5	61.9
Nitrogen index, mg/100 plants		0.58	0.63	0.58	0.58	0.62
Spring barley, Nutans 553 variety						
Content of N in plants during flowering, %		4.1	4.2	4.2	4.3	4.4
Content of N in plants during full ripeness, %	grain	2.4	2.8	2.8	2.5	2,6
	straw	0.9	1.1	1.1	0.8	0,8
	total	3.3	3.9	3.9	3.3	3,4
N outflow efficiency to grain, %		72.7	71.7	71.7	75.8	76.4
Nitrogen index, mg/100 plants		0.73	0.72	0.72	0.76	0.76

The content of nitrogen in the grain of spring wheat during the phase of full ripening was maximum in the trial variant with pre-drilling seed dressing with Flavobacterin and Rhizoagrin-204, which was 2.4 – 2.6%. The completeness of nitrogen outflow to the grain exceeded the control variant and was equal to 61.9% - 63.2%, the nitrogen index was 0.63-0.62 mg/100 plants. Spring barley performance was better in 2 trial variants with pre-drilling seed dressing with Agrophil and Rhizoagrin-204. The completeness of nitrogen outflow to the grain was 75.8-76.4% and the nitrogen index was 0.76 mg/100 plants.

Table 1. Structure of consumptive water use by spring crops in 2011-2014.

ear	Precipi tations during the period of germination-harvesting, mm		Irrig ation water, mm		Pro ductive water reserve in the soil before vegetation, mm	Pro ductive water reserve in the soil at the end of vegetation, mm	Moist ure consumption from the soil during vegetation, mm		Cons umptive water use, m³/ha
	m		m		mm	mm	m		
011	0.5	1.5	75.0	8.0	54.1	17.3	6.8	0.4	3523.0
012	4.0	6.8	75.0	2.3	58.8	17.7	1.1	0.8	3801.0
013	0.0	8.4	75.0	0.8	61.4	18.1	3.3	1.2	3883.0
014	2.9	1.9	75.0	6.1	59.7	16.1	3.6	2.1	3615.0
ean	**4.4**	**4.7**	**75.0**	**4.3**	**58.5**	**17.3**	**1.2**	**1.1**	**3706.0**

Influence of pre-drilling inoculation with microbiologic seed dressing on the symbiotic activity of spring crops cultivated on light-chestnut soil

The performed field trials revealed a significant correlation between the microbiological *activity* of the soil and the pre-drilling seed inoculation with different microbiological products (Agrophil, Mizorin, Flavobacterin, and Rhizoagrin-204). More detailed studies of the soil biodynamics by the method of linen loss of mass revealed two variants that were characterized by a higher intensity and activity of cellulose-degrading microorganisms (Table 2).

Table 2. Biological activity of light-chestnut soil (loss of linen dry mass, %) of Saratovskaya 70 spring wheat, mean for 2011-2014.

Variant	Wight of linen before the trial, g	Wight of linen after the trial, g	Loss of linen dry mass, %
V1 (control), no dressing	4. 2	2.2	52
V2 (Flavobacterin)	4. 2	2.8	66
V3 (Mizorin)	4. 1	2.9	70
V4 (Agrophil)	3. 0	2.1	58
V5 (Rhizoagrin-204)	3. 7	2.4	65

Such variants included the seed dressing with Rhizoagrin-204 (65% of linen dry mass loss), Flavobacterin (665), and Mizorin (70%). The performed analysis showed not only the activity of cellulose degrading microorganisms but also the degree of mobilization of nitrogen in the soil. Besides, the evaluation of the intensity of linen degradation by this method reflected the condition and activity of soil microflora more objectively

Table 3. Elements of yield structure of Saratovskaya 70 spring wheat on light-chestnut soil, mean for 2011-2014.

Variant	Mean number of kernels per ear, pcs.	KW, g	Mean number of productive stems before the yield, pcs/m^2	Mean grain weight per year, g	Biological yield, t/ha	Increase in comparison with the control, t/ha
V1 (control), no dressing	18.2	0.8	458	0.61	2.8	-
V2 (Flavobacterin)	20.3	3.8	493	0.65	3.2	0.4
V3 (Mizorin)	20.3	3.4	506	0.63	3.2	0.4
V4 (Agrophil)	20.9	3.0	489	0.81	4.0	1.2
V5 (Rhizoagrin-204)	19.9	0.6	477	0.70	3.4	0.6

Table 4. Elements of yield structure of Nutans 553 spring barley on light-chestnut soil, mean for 2011-2014.

Variant	Mean number of kernels per ear, pcs.	TKW, g	Mean number of productive stems before the yield, pcs/m^2	Mean grain weight per year, g	Biological yield, t/ha	Increase in comparison with the control, t/ha
V1 (control), no dressing	14.4	43.5	490	0.90	4.4	-
V2 (Flavobacterin)	14.6	46.0	500	0.96	4.8	0.4
V3 (Mizorin)	15.3	45.3	507	0.96	4.9	0.5
V4 (Agrophil)	14.7	44.6	503	0.91	4.6	0.2
V5 (Rhizoagrin-204)	14.4	44.2	492	0.95	4.7	0.3

The analysis of the structure of the yield elements of Saratovskaya 70 spring wheat variety with pre-drilling seed dressing with microbiological products revealed the maximum productivity in the variant with Agrophil. Mean number of kernels per ear was 20.9 pcs, TKW was 330 g, mean weigh of grain per ear was 0.81g, and the yield was 4.0 t/ha. Spring barley Nutans 553 had high parameters of yield in two trial variants with Mizorin and Flavobacterin. The grain in the ear was well-formed. The mean weight of grain per ear was 0.96 g. The biological yield was 4.8 – 4.9 t/ha.

4. Conclusions

1. In the soil climatic conditions of the Astrakhan Region, the cultivation of spring crops with pre-drilling seed dressing with microbiological products is an important agrotechnological

approach that provides high yield, which was proved by the results of the performed trial in the irrigated soil.

2. The application of nitrogen-fixing microbiological products showed its growth-stimulating activity, which primarily influenced the redistribution of nitrogen between the vegetative and reproductive organs of grain crops as well as the cellulose-degrading capacity.

3. The maximum yield increase ranged from 0.5 to 1.2 t/ha (in comparison with the control variant) in the variants that involved Flavobacterin, Mizorin, and Agrophil. Biological yield was 4.0 t/ha in spring wheat and 4.8 – 4.9 t/ha in spring barley.

4. In the conditions of light chestnut alkaline soil of the Astrakhan Region as well as other arid regions, the cultivation of grain crops with pre-drilling seed dressing with microbiological products is an important agrotechnological approach that provides the yield higher than 5 t/ha.

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