The effectiveness of biological products in the steppe conditions of the Central Chernozem region

A Yu Cheverdin\textsuperscript{1} ORCID 0000-0003-2621-0957, M Yu Sautkina\textsuperscript{2} ORCID 0000-0001-9244-1177, Yu I Cheverdin\textsuperscript{1} ORCID 0000-0002-9905-0547

\textsuperscript{1}Voronezh Federal Agricultural Scientific Centre named after V.V. Dokuchaev, Voronezh, Russia
\textsuperscript{2}All-Russian Research Institute of Forest Genetics, Breedings and Biotechnology, Voronezh, Russia

E-mail: cheverdin62@mail.ru; sautmar@mail.ru

Abstract. In the steppe conditions of the Central Chernozem region, the effectiveness of biologics based on associative microorganisms in the crops of spring barley and winter triticale was studied. The effectiveness of biological products was evaluated on two fertilization backgrounds: the natural background of mineral nutrition (without fertilizers) and pre-sowing nitrogen application at a dose of 30 kg / ha of the active substance. The studies carried out in the steppe conditions of the Central Forest District, with insufficient moisture supply, allowed us to establish a high responsiveness of cultivated plants to pre-sowing seed treatment with drug strains. In barley crops, mineral nitrogen contributed to an increase in productivity by 0.26 t/ha. Seed inoculation contributed to an increase in grain harvest by 0.31–0.52 t/ha. The greatest increase in single application was provided by strains 7, 2P-7 and 204. Higher yield growth was observed in the binary application of strains 7, 30, 204 in combination with strain 8. The productivity of triticale in the conditions of the Central Processing Plant was higher than that of barley. Mineral nitrogen increased the yield of triticale by 0.33 t/ha. On a natural background, microbial strains increased grain harvest by 0.55 t/ha. The maximum effect was observed when inoculated with strain 18-5. The combined use of microbial strains with nitrogen fertilizer did not contribute to a further increase in the productivity of triticale.

1. Introduction
Chernozem soils of the steppes of Russia have a long period of agricultural use. As a result of active anthropogenic impact, degradation processes are observed, causing a decrease in the effective fertility of the original soils. Many works have been devoted to studying the characteristics of chernozems and optimizing their properties [1-9]. As a result of purposeful human activity, especially during the last century, modern high-intensity agricultural landscapes have been formed.

One of the key components of natural landscapes is the virgin steppes, which as a result of agrogenesis have been transformed into modern agricultural landscapes. The man-made forest-cultural landscape of the Stone Steppe, founded by V.V. Dokuchaev, is still a unique scientific object that allows conducting long-term multi-faceted monitoring studies [10, 11].

One of the main distinguishing features of modern agricultural production is the lack of resource availability. First of all, the doses of applied mineral fertilizers were significantly reduced. There is a shortage of the main elements of mineral nutrition, the effective fertility of the soil decreases. The key element that ensures high yields is the availability of mineral nitrogen in the soil. The high cost of...
mineral fertilizers constrains the pace of increasing use in agriculture. Many scientific institutions are searching for alternative sources of plant nutrition, and scientific research in this direction is being intensified. An important source of nitrogen for plant nutrition is biological nitrogen, which is fixed in the rhizosphere of plants. And not the least role in this regard is played by associative diazotrophic microorganisms that live in the rhizosphere of cereals. The role of diazotrophic preparations in increasing plant productivity, resistance to adverse environmental factors (drought, high temperature background), salinity, acidity, etc. is significant [12, 13, 14]. On soils with low fertility, the role of biological products in increasing plant productivity increases [15]. The use of microbial strains reduces the load of mineral fertilizers on the environment, increases the availability of soil nitrogen to plants [16]. In this regard, it is necessary to search for alternative sources of mineral nutrition of plants and to stabilize soil fertility. One of the ways to solve this problem is the use of biological products based on associative strains in the crops of cereals.

The aim of the research is to study the effect of presowing inoculation of spring barley and winter triticale seeds by associative strains on the change in grain yield in the conditions of the Central Processing Plant.

2. Materials and Methods
Field studies were conducted at the Voronezh Dokuchaev FANC in 2012-2018. The background soil of the experimental site is represented by segregated (ordinary) medium-humus chernozem of heavy loamy granulometric composition.

The content of humus – 6.8%, pH-7.2, Nq-0.7 mmol eq/100 g of soil. Exchange bases: Ca - 24 – 26 mmol eq/100 g; Mg – 4 - 5 mmol eq/100 g. The degree of base saturation is very high-96-98%. The research was carried out on two crops: spring barley of the variety Natalovsky 9, winter triticale of the variety Doctrine 110. The predecessor is cereals. Diazotrophic preparations for presowing inoculation of seeds were tested. The strains of microbial preparations were obtained from the All-Russian Research Institute of Agricultural Microbiology. Inoculation of grain seeds was carried out directly on the day of sowing. The scheme of the experiment provided for conducting research on a natural background and when applying nitrogen fertilizers at a dose of 30 kg / ha d. v. Mineral fertilizers were applied manually for pre-sowing cultivation. The area of the plots of the last or order is 5 m², the repetition is sixfold. The grain yield was determined by the method of continuous division accounting according to Dospekhov B.A. [17].

3. Results and Discussion
From an agronomic point of view, the greatest interest is the change in the yield of cultivated crops under the influence of methods of intensification of crop production. It is a resultant indicator of the factors that determine the growth and development of plants. The analysis of the conducted studies shows that the main reason for the growth of grain productivity is diazotrophic microorganisms. The yield of spring barley grain in the non-fertilized variant was 2.28 t/ha (table 1). Presowing inoculation of seeds with associative strains provided a significant increase in yield increases - from 0.31 to 0.42 t/ha. The best indicators were noted when using strains 7, 204 and 2P-7. The yield was 2.69, 2.70 and 2.68 t/ha, respectively. Productivity growth was about the same. The maximum increase in grain harvest on the variant without fertilizing barley was observed when using binary seed treatments with two strains of rhizobacteria. The combination of strains 30 and 8 contributed to the production of 2.80 t/ha of grain, strains 7 and 8-2.73 t/ha.

The effectiveness of the complex application of biologics strains against the background of nitrogen fertilizer was noticeably lower. The use of one nitrogen fertilizer increased productivity to 2.54 t/ha (by 0.26 t/ha). In the variants with seed inoculation, the yield varied in the range from 2.18-2.75 t/ha. For some strains, a negative effect was noted, which even led to a decrease in yield. Thus, we can state a significant increase in yield under the influence of rhizobacteria, which is not inferior in its effect to mineral nitrogen. Stimulating the ability of cereal crops to use biological nitrogen instead of chemically synthesized forms of it can become a serious factor in the growth of grain productivity.
of barley. The use of associative strains improves the transport of mineral elements from the soil of the root zone, increases the intake and accumulation in the vegetative mass. And ultimately contributes to the growth of productivity.

In the initial stages of organogenesis of spring barley plants, mineral fertilizers have a positive effect on the amount of available nitrogen in the soil, activate growth processes. As plants develop during the growing season, there is a gradual decrease in nitrogen concentration due to consumption by cultivated plants and soil biota. It can be assumed that the application of mineral fertilizers for pre-sowing cultivation, even in small doses against the background of microbial strains, reduces the associative nitrogen fixation at the subsequent stages of plant development.

### Table 1. Barley yield, t/ha, average for 2015-2018.

| Bacterial preparation (factor B) | Background of mineral nutrition (factor A) | Average |
|----------------------------------|------------------------------------------|---------|
| Without fertilizers | N<sub>30</sub> | |
| Control | 2.28 | 2.54 | 2.41 |
| Strain 7 | 2.69 | 2.60 | 2.65 |
| Strain 8 | 2.62 | 2.18 | 2.40 |
| Strain 17-1 | 2.61 | 2.45 | 2.53 |
| Strain 18-5 | 2.65 | 2.63 | 2.64 |
| Strain 30 | 2.59 | 2.65 | 2.62 |
| PG-5 strain | 2.61 | 2.46 | 2.53 |
| Strain 204 | 2.70 | 2.67 | 2.69 |
| Strain 2P-7 | 2.68 | 2.63 | 2.66 |
| Strains 7 + 8 | 2.73 | 2.75 | 2.74 |
| Strains 30 + 8 | 2.80 | 2.65 | 2.73 |
| Control | 2.68 | 2.71 | 2.69 |
| **Average** | **2.64** | **2.58** | |

NSR 0.95 strains 0.04-0.16 t/ha
fertilizers 0.06-0.14 t/ha

Statistical processing of experimental data on the evaluation of the main effects of the two-factor experiment shows the different significance of the studied factors in the formation of the crop. Microbial preparations had the greatest impact on the yield of barley grain. Their share varied from 21.9% to 55.7% over the years. Mineral nitrogen was significantly inferior in this respect. The contribution to the formation of the crop varied over the years from 1.0 to 18.1%. Under conditions of lack of atmospheric moisture and high temperatures in the second half of the growing season, the role of microbial preparations increased.

It is necessary to note the high effectiveness of microbial preparations in winter triticale crops. Despite the fact that the period from processing to the beginning of the formation of reproductive organs passes a long period (autumn-winter-spring). But, despite this, microbial strains retain their activity for a long time.

The highest yield of winter triticale grain with pre-sowing inoculation was obtained on the natural background of mineral nutrition. At the control yield level of 2.97 t/ha, it increased under the influence of microbial strains to 3.12-3.52 t/ha (table 2). The highest increase was characterized by associative strains 18-5, 17-1 and 30 [16]. The yield growth was 0.47 - 0.55 t/ha.

As a result of our research in 2012-2015, we can conclude that the most effective associative diazotrophs affected the yield of winter triticale on a non-fertilized background. The most active was pc. 18-5. The average yield over the years of research on the variant with this strain was 3.52 t/ha, which is 18.5% higher than the control.

The fact that the greatest effect was observed on the variants without fertilization indicates the adaptive effect of microbial strains. Pre-sowing inoculation of seeds increased the resistance of plants to
adverse environmental factors, increased and stimulated the development of the root system and aboveground mass.

**Table 2. Yield of winter triticale in 2012-2015, t/ha.**

| Experience options | Fertilization background | N30 |
|--------------------|--------------------------|-----|
| Control            | Without fertilizers      | 2.97| 3.30 |
| Strain 7           |                          | 3.16| 3.25 |
| Strain 8           |                          | 3.38| 3.38 |
| Strain 17-1        |                          | 3.44| 3.22 |
| Strain 18-5        |                          | 3.52| 3.24 |
| Strain 30          |                          | 3.45| 3.37 |
| PG-5 strain        |                          | 3.41| 3.34 |
| Strain 204         |                          | 3.33| 3.26 |
| Strain 2P-7        |                          | 3.12| 3.25 |
| Strain 33-3        |                          | 3.28| 3.23 |
| NSR0.95 strains    | 0.05-0.2 t/ha            |     |
|                    | fertilizers 0.01-0.13 t/ha|     |

4. Conclusion

It is proved that on chernozems with an average supply of mineral nutrition elements, the most optimal for the activity of soil diazotrophs is the natural background of fertilization. Thus, the increase in the productivity of spring barley was up to 0.52 t/ha, winter triticale-up to 0.55 t/ha In spring barley crops, high efficiency was provided by the use of strains 7, 2P-7 and 204. Grain harvest increased by 0.32, 0.31 and 0.30 t/ha, respectively. The maximum increase in the yield of barley is observed with the binary use of strains 7 (mizorin)+8 (azorizin); 30 (flavobacterin)+8(azorizine) and 204 (rizoagrin)+8 (azorizin) - from 0.30 to 0.52 t/ha.

In winter triticale crops, the maximum productivity was provided by inoculation of seeds with strains 18-5, 17-1 and 30 - 3.52; 3.44 and 3.45 t/ha (control-2.97 t/ha). However, the complex pre-sowing application of mineral nitrogen at a dose of N30 in combination with seed inoculation by associative microorganisms did not contribute to a stable increase in the yield of winter triticale.

Thus, the use of associative microbial preparations for pre-sowing inoculation of seeds will allow to adjust the doses of applied mineral fertilizers in modern agricultural technologies, and to reduce the agrogenic load without the risk of reducing the productivity of grain crops.

References

[1] Breskina G V and Chuyan N A 2018 Structure of energy reserves and ecological capacity of agroecosystems of the agricultural landscape Ecological problems of agricultural landscape development and ways to increase their productivity Krasnodar, March 27-29, 2018 pp 61-63

[2] Gostev A V, Pykhtin I G, Nitchenko L B, Plotnikov V A and Pykhtin A I The system for assessing the ecological balance of the agricultural landscape and the degree of compliance of the farming system used in it Agriculture 8 pp 3-6

[3] Polyakov D G, Bakirov F G, Khalin A V and Nesterenko Yu M 2017 Transformation of the salt profile of Southern chernozem under the influence of methods of basic soil treatment
Pykhtin I G, Dubovik D V and Aidiev A Ya 2018 Current problems of agriculture. Agriculture. 5 pp 8-11 doi: 10.24411/0044-3913-2018-10502

Uvarov G I 2018 Ecological functions of soils Study guide (Saint Petersburg: Publishing house "Lan") p 296

Shapovalov D A, Koroleva P V, Dolinia E A and Rukhovich D I 2018 Assessment of the impact of waterlogging on the change of land use types of arable land in the Tambov region in 1968-2018 by methods of retrospective monitoring of soil and land cover. Scientific Bulletin of the Belgorod State University. Series: Natural Sciences vol 42 3 pp 358-379

Bazikina G S and Ovechkin S V 2016 The influence of climate cycles on the water regime and carbonate profile in chernozems of central European Russia and adjacent territories. Eurasian Soil Science 49(4) pp 437-449

Chendev Y G, Novykk L L, Petin A N, Petina V I, Zazdравnkh E A, Sauer T J, Gennadiev A N and Burras C L 2015 Accumulation of organic carbon in chernozems (mollisols) under shelterbelts in Russia and the United States. Eurasian Soil Science 48 1 pp 43-53

Collins H P, Elliot E T, Paustian K, Bundy L G, Dick W A, Huggins D R, Smucker A J M and Paul E A 2000 Soil carbon pools and fluxes in long-term corn belt agroecosystems. Soil Biol. Biochem vol 32 2 pp 157-168

Prikhodko V E, Cheverdin Yu I and Titova T V 2013 Changes in the forms of organic matter of chernozems of the Stone Steppe with different use, location, and increase in the degree of hydromorphism. Soil science 12 pp 1494-1504

Khitrov N B and Cheverdin Yu I 2016 Soils of the Stone Steppe from V V Dokuchaev to our days. Zhivye i biokostnye sistemy SFU p 2

Kiryushin V M 2000 Ecologization of agriculture and technological policy (Moscow: MSHA Publishing House) p 473

Tikhonovich I A, Zavalin A A and Bгаговеshchenскaya G G and Kozhemyakov A P 2011 The use of biological products – an additional source of plant nutrition elements. Fertility 3 pp 9-13.

Zavalin A A 2015 Optimization of mineral nutrition and plant productivity when using biological products and fertilizers. The achievements of science and technology APK vol 29 5 pp 26-28

Sautkina M Yu and Cheverdin Yu I 2020 Influence of biological preparations based on associative on the yield of winter triticale in the conditions of the south-east Central Chernozemic Area. 6th International Conference on Agriproducts processing and Farming. IOP Conf. Series: Earth and Environmental Science vol 422 (2020) 012028 IOP Publishing (6th International Conference on Agriproducts Processing and Farming 17–18 October 2019, Voronezh, Russian Federation) doi:10.1088/1755-1315/422/1/012028

Torosov V I, Sautkina M Yu, Cheverdin A Yu and Cheverdin Y I 2016 The Influence of biopreparations associative diazotrophs on the yield of grain crops in the South-East of the Central Chernozem region. The achievements of science and technology APK vol 30 5 pp 38-42

Dospekhov B A 1985 Methodology of field experience (Moscow: Agropromizdat) p 351