Technological platform for the cultivation of barley in the Krasnoyarsk forest-steppe

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Abstract. The results of the research aimed at developing a technological platform for the cultivation of barley are presented. The technological platform is a pyramid of seven biogenic energy flows. At the base of the pyramid there are streams with sustainable natural potential. They include the conditions of the territory (climate, weather and soil with its natural level of fertility). They mainly determine the choice of variable flows - crop, variety and cultivation technology. The most changing factor with a wide range of changes is the cultivation technology. The technology is directly dependent on the soil, the climate, and the weather and is closely related to anthropogenic impact. The main variable fluxes of biogenic energy include the availability of available moisture, nutrients and weediness of crops. The tillage is the regulated, most costly energy flow. In the experiment, soil cultivation was carried out according to the traditional technology based on fall tillage (control) and minimal. Herbicide treatment allowed to reduce the contamination of the crop for harvesting by 60%. The harvest was formed in harsh weather conditions, grain. Wheat grains, on average, were obtained at 29.2 c / ha, barley - 22.0 - 26.5 c / ha.

1. Introduction

The work is carried out within the framework of the State Task: Optimization of agricultural management of nature, agro-ecological assessment of lands, creation of adaptive farming systems and new generation agricultural technologies based on digitalization and regulation of flows of biogenic elements in agro-ecosystems.

A more complete realization of the natural resource potential is possible with the optimal share of high-yielding crops in the structure of sown areas, taking into account the concepts that characterize the basic natural characteristics of the land plot and the most significant aspects of natural processes [1, 2].

Barley is the oldest cultivated plant, grain contains 68% of carbohydrates, up to 18% of protein, 2% of fat, 2% of ash, 5% of fiber, 9-11% of crude protein [3, 4]. The protein complex of barley grain includes more than 20 amino acids, incl. 8 which are irreplaceable. The most important of them are lysine, tryptophan, methionine, threonine [5].

The unique amino acid and carbohydrate composition of barley grain determines a wide range of its use, primarily for the production of pearl barley, barley groats, and the preparation of feed rations [6].

The diverse use of the crop necessitates an increase in grain harvests because of an increase in the yield on the basis of improving the technology of cultivation of barley in the conditions of the Krasnoyarsk forest-steppe [7, 8].

New varieties of barley of the Krasnoyarsk Research Institute of Agriculture selection were grown after wheat, on pure fallow in the experiment in field crop rotation. The yield level on pure fallow is in
the range of 3-4 t/ha. The choice of the predecessor is caused by the structure of crops of grain and leguminous crops recommended by the Farming System of the region and the high contamination of the soil with weed seeds in the forest-steppe conditions [9].

2. The purpose of the research

The study of the influence of the flux of some biogenic elements in the agroecosystem of the Krasnoyarsk forest-steppe on the yield of barley. We studied the effectiveness of the influence of various conditions and factors that make up the technological platform on the productivity of Emelya barley in the Minino Experimental Production Farm (EPF), the Emelyanovskiy district, the Krasnoyarsk Region.

3. Research methodology

In 2017-2020, field and laboratory studies were carried out according to generally accepted methods on the experimental fields of the multiyear station with geographical coordinates: 56° 03 min. north latitude, and 92° 42 min. east longitude [10,11]. Modern technical means were used (MTZ tractor - 82, SZS sower -2.1), instruments and laboratory equipment: soil thermometers, seed dressing unit, soil drill, laboratory scales, drying cabinet, density meter and others. The assessment of the humus content in the plow layer was carried out in accordance with the recommendations [12,13,14].

The climate of the zone is sharply continental [15]. The weather presents 9 types of varied weather conditions. The soil is ordinary chernozem. Crop - barley, Emelya variety. The predecessor is spring wheat on black fallow. The technology is traditional, based on plowing. Minimal, with disk tillage.

Ammonium nitrate in the experiment was introduced before sowing in an amount of 34.4 kg of ai. per 1 hectare.

Sowing of seeds was carried out in the period from May 24-29 with a SZS -2.1 sower. The seeding rate is 3.5 million viable grains per hectare, the depth is 6-7 cm. Protection of plants from weeds consisted of crops treatment during tillering in 2017, 2019 by tank mixture of herbicides Puma Super (0.4-0.6 l/ha) + Magnum (8 g/ha), in 2018 – by tank mixture of herbicides Primadonna Super KKR (0.4-0.6 l/ha) + Zinger SP, (6-8 g/ha) + Ovsyugen Express, EC (0.4-0.61/ha).

The placement of the variants in the territory is regular, the accounting area of the variant is 40.6 m², the experiment is repeated 3 times. Statistical processing of the research results was carried out using the Snedecor software package [16].

4. Results and its discussion

To improve the cultivation technology, the conditions and factors involved in the process were combined into a technological platform, including the main sources of biogenic elements.

1. Climate. The average multiyear (since 1982) indicator of annual precipitation, according to the data of EPF "Minino", is 362 mm. For the period May-August, 211 mm fall. The maximum annual air temperature was on average + 1.8°C, the minimum - minus 1.1°C; average - + 0.5°C. The sum of temperatures above + 5°C = 2215°C, above + 10°C = 1750°C [17].

2. The weather conditions of the research area according to combinations of air temperature and precipitation amount characterize periods as dry - cold, dry - warm, wet - cold and wet - warm, as well as average or with intermediate indicators.

Growing seasons 2017 - 2019 differed in the lack of precipitation by 9 mm less than the average multiyear level. In total, 109 - 299 mm fell during the growing season at an average air temperature of 16 °C (Table 1 and 2).
Table 1. Distribution of average daily temperatures and precipitation for the growing season of barley (EPF "Minino").

| Months | Temperature, °C | Precipitation, mm |
|--------|-----------------|-------------------|
|        | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| May    | 11   | 9    | 10   | 36   | 33   | 20   |
| June   | 20   | 20   | 18   | 48   | 28   | 44   |
| July   | 19   | 18   | 19   | 61   | 28   | 80   |
| August | 17   | 18   | 18   | 154  | 20   | 58   |
| Average, May-August | 17 | 16 | 16 | 299 | 109 | 202 |

The average multiyear coefficient of the ratio of precipitation and the sum of air temperature indicators "K" was 1.14. Years of the research have an indicator of 1.03, which indicates more arid conditions, especially in 2018, the coefficient was 0.55.

Table 2. Coefficient of the ratio of precipitation and average daily air temperature for the vegetational season (EPF "Minino").

| Year    | May   | June  | July  | August | Average, May-August |
|---------|-------|-------|-------|--------|---------------------|
| 2017    | 1.05  | 0.8   | 1.03  | 2.92   | 1.42                |
| 2018    | 1.18  | 0.47  | 0.5   | 0.36   | 0.55                |
| 2019    | 0.48  | 0.81  | 1.35  | 1.04   | 1.02                |
| 2017-2019 | 0.96 | 0.7   | 0.95  | 1.38   | 1.03                |
| Average multiyear | 1.00 | 1.10 | 1.10 | 1.20 | 1.14 |

3. The soil of the station is represented by ordinary chernozem, medium-thick, medium-powered, medium-loamy. The humus content in the 0–20 cm layer is 8.36–8.72%, pH H2O 7.1–7.8. The sum of exchangeable bases is (40.0–45.5 meq / 100 g), the content of P2O5 is in the range of 50.4–67.4 mg / kg, K2O is about 214.0–269.0 mg / kg (according to Machigin). The limiting field moisture capacity of a meter layer is 323 mm; stable wilting of plants occurs at a moisture content of 11.7%, equal to 1.5 levels of maximum hygroscopy. Fertility indicators correspond to the requirements for the cultivation of barley [18,19].

Barley cultivation technology includes the soil cultivation system, the fertilization system and the plant protection system. Soil preparation in the experiment is carried out according to the scheme: 1. fall plowing (control). 2. autumn disking (experiment), the sowing was carried out with a stubble seeder SZS - 2.1. Herbicide treatment was carried out in the barley tillering phase.

The primary task that is solved in the system of basic tillage is to create a favorable structure of the arable soil layer. Measurement of soil density with a Willi density meter after harvesting and in spring before sowing showed that the density value in the 0-40 cm horizon does not exceed 21 kg / cm²; it is located in the green (normal for plants) or yellow (permissible) sector of the scale.

The structure of the arable layer, after several years of implementing various tools, is in excellent and good condition. Moisture and temperature conditions at which the density in the 0-10 horizons and up to 80 cm is in the normal or acceptable level for plants. Before sowing, the bulk density of the 0 - 10 cm layer after plowing was 0.87 g / cm³, in the disking version, within 0.99 g / cm³. limits. At the same time, the cultivated crop did not affect the studied indicator.
The content of available moisture in the soil. Meteorological conditions during the observation period, the type of phytocenosis, the type, method and methods of soil cultivation determine a significant variation in the level of available moisture content. Minimization of tillage allowed to accumulate on the soil surface a mulching layer of plant residues and chopped straw within the range of 12 t / ha., contributing to the preservation of available moisture in the 0-20 cm layer, for sowing. Moisture reserves for plowing were about 18 mm, after disking 25 mm.

During the growing season of a crop, the dynamics of productive moisture reserves is largely determined by meteorological conditions. In years favorable for moisture, the moisture content in the 0–20 cm layer can reach 30 mm by the full sprouts stage (early June), and in the meter layer - 160 mm.

Earing of cereals is accompanied by about 56 mm of precipitation, no deficit of available moisture in the soil was observed. This is confirmed by visual observations of the state of the plants. By the middle of the growing season (July 20), the moisture content in the 0-50 cm layer, the plowing option, decreased to 7 mm, in the meter layer - up to 5 mm, on disking - up to 13...17 mm.

Plant food compounds. The provision with nitrate nitrogen before sowing barley corresponds to the 2nd class and amounted to 4.0 - 6.8 mg / kg of soil, therefore, ammonium nitrate was introduced in an amount of 1 c / ha. The supply of mobile phosphorus and exchangeable potassium during the growing season was at an increased and high level. There was no lack of nutrients for plants during the growing season. Consequently, in order to more fully use the potential of nutrients, it is advisable to increase the density of the productive stalk by increasing the seeding rate from 3.5 to 4 - 4.5 million viable grains per hectare.

Contamination of crops. Chemical protection of plants from weeds consisted in the treatment of barley crops in the tillering stage. In 2018, the treatment was carried out with a tank mixture of herbicides Primadonna Super KKR (0.4-0.6 l / ha) + Singer SP, (6-8 g / ha) + Ovsugen Express, EC (0.4-0.6 l / ha). To exclude the addiction of weeds to the preparation, in 2017 and 2019, a tank mixture of herbicides Puma Super (0.4-0.6 l / ha) + Magnum (8 g / ha) was used. Herbicide treatment allowed to reduce the contamination of the crop for harvesting by 60%.

Against the background of a high contamination by annual weeds with a predominance of growing in grain fields millet, an increase in the foci of couch grass was noted on the option of minimal tillage (disking).

Yield is an integral indicator of the efficiency of the technology for the cultivation of cereals. as a predecessor of barley, wheat on fallow in 2016-2020. formed grains on average at 18.0 - 41.0 c / ha. Barley yield in the control and experimental variants (plowing and disking without fertilizers) for 2017-2019 was on average 22 c / ha (Table 3).

| Tillage (A) | Background (B) | Sowing time/harvesting | Average 2017-2019 |
|-------------|----------------|------------------------|-------------------|
|             |                | Год | 24.05.–09.09.2017 | 29.05.–12.09.2018 | 28.05.–12.09.2019 |
| plowing     | Without fertilizers | 22.1 | 20.7 | 23.4 | 22.0 |
|             | Fertilized     | 26.1 | 25.1 | 25.7 | 25.6 |
| disking     | Without fertilizers | 23.2 | 21.1 | 21.9 | 22.1 |
|             | Fertilized     | 28.9 | 25.9 | 24.8 | 26.5 |
| среднее     | Without fertilizers | 22.6 | 20.9 | 22.6 | 22.0 |
|             | Fertilized     | 27.5 | 25.5 | 25.2 | 26.1 |
| LSD05 ц/га | A – tillage 1.5; B – fertilizer 1.8 | 1.5 | 1.8 | 1.5 | 1.8 |
Fertilization with ammonium nitrate in the amount of 1 c / ha increased costs by 39% and increased yields by 16.3-19.9%. By plowing, the yield increased by 3.6 c / ha, for the option of minimum tillage - by 4.4 c / ha (LSD$_{0.05}$ = 1.8 c / ha). The efficiency of ammonium nitrate in 2017, with a greater amount of summer precipitation (the moisture coefficient was 1.42), is higher compared to 2018 and 2019. The yield increase from the use of ammonium nitrate was 5.1 c / ha. With less precipitation in 2018 and 2019, the yield increase was 3.6 c / ha.

Economic efficiency is expressed in reducing costs on tillage while minimizing it, reducing costs were 12.6%, the fuel economy was 42.6%.

5. Conclusion
Soil and climatic conditions are the basis of the technological platform for the cultivation of spring barley in the forest-steppe zone of the Krasnoyarsk Region.

When growing barley in the experiment after wheat on the fallow in the conditions of 2017-2019 grain yield was 22.0 c / ha. The differences between the tillage options are not significant.

The use of ammonium nitrate in the amount of 1 c / ha in physical weight, allows to increase the grain yield on the option of traditional tillage by 16.3%, on the minimum tillage - by 19.9%.

Application of resource-saving tillage technology reduces costs by 12.6%, fuel consumption is 42.6% lower than with traditional technology with fall plowing.

Treatment with herbicides made it possible to reduce the contamination of crops for harvesting by 60%.

References
[1] Akimenko A S 2020 Formation of crop rotations and the structure of sown areas to obtain a given amount of products, taking into account the natural resource potential Zemledelie 4 19-22 Doi: 10.24411 / 0044 - 3913 - 2020 - 10405.
[2] Kalichkin V K, Koryakin R A, Maksimovich K Yu, Sigitov A A and Galimov R R 2020 Conceptual model of agroecological properties of lands Siberian Bulletin of Agricultural Science 50(1) 72-80 Doi: 10.26898 / 0370 - 8799-2020 - 1-9.
[3] Surin N A, Lyakhova N E, Gerasimov S A and Lipshin A G 2016 Biological features and breeding significance of barley varieties of the Siberian breeding Siberian Bulletin of Agricultural Science 1(248) 13-22
[4] Surin N A, Lyakhova N E, Gerasimov S A and Lipshin A G 2018 implementation of the ideas of n.i. vavilova in barley breeding in Siberia Works on applied botany, genetics and breeding 179(1) 78-88
[5] Surin N A and Gerasimov S A 2019 Inheritance of productive tillering by hybrids of spring barley Achievements of science and technology of the agro-industrial complex 33(7) 5-8 DOI: 10.24411 / 0235-2451-2019-10701.
[6] Surin N A 2011 Adaptive potential of varieties of grain crops of Siberian selection and ways of improving it (wheat, barley, oats) (Novosibirsk: Krasnoyarsk. scientific research in-t sat. households)
[7] 2016 Agro-industrial complex of the Krasnoyarsk Region in 2011 – 2015 (Krasnoyarsk)
[8] Brylev S V 2015 The system of agriculture of the Krasnoyarsk Region on a landscape basis (Krasnoyarsk)
[9] Brylev S V 2011 Results of work and development prospects of the plant growing industry in the Krasnoyarsk Region (Krasnoyarsk) p 4
[10] 2018 Guidelines for the registration tests of agrochemicals in agriculture (Moscow)
[11] Dospekhov B A 1985 Field experiment technique (M.: Agropromizdat)
[12] Alexandrova L N and Naydenova O A 1967 Laboratory and practical classes in soil science (L.: Kolos)
[13] Kachinsky N A 1970 Soil physics (M.: Higher school)
[14] Kozhevnikov N V 2016 Influence of basic tillage techniques on the content and reserves of humus
in ordinary chernozem of the Krasnoyarsk forest-steppe Reflection of bio-, geo-, anthropospheric interactions in soils and soil cover. Materials of the VI All-Russian Scientific and Practical Conference (Tomsk, 2016) pp 288-91

[15] Shpedt A A and Trubnikov Yu N 2020 Methodology for assessing the natural resource potential of agricultural landscapes in Russia Living and bio-inert systems 31 URL: https://jbks.ru/archive/issue-31/article-1.

[16] Demidenko G A and Romanov V N 2016 The influence of herbicides on the productivity of spring wheat in the forest-steppe zone of the Krasnoyarsk Region Bulletin of OmGAU 2(22) 11-5

[17] Sorokin O D 2004 Applied statistics on a computer (Novosibirsk)

[18] Agrometeorological bulletins of AMC "Minino" 2017-2019

[19] Belash M Yu, Veprikova E V, Sobolev A A, Romanov V N, Kozulina N S, Snitkova T A, Vasilenko A V, Mikhailets M A, Lipshin A G and Taran O P 2020 Development of nitrogen-containing fertilizer based on pine bark and study of its effectiveness in wheat growing in the agricultural zone of the krasnoyarsk territory J. Sib. Fed. Univ. Chem. 13(4) 578-92 DOI: 10.17516 / 1998-2836-0207.

[20] Kozulina N S, Vasilenko A V, Vasilenko A A and Shmeleva Zh N 2020 Substantiation of the ecological method application for disinfection and biostimulation of spring wheat seeds in the Krasnoyarsk territory forest-steppe zone IOP Conf. Ser.: Earth Environ. Sci. 548 052034