Analysis of the formation of productivity of artificially created mixtures in different biotypes of barley

V V Bogdanov, T V Onufrienok and A A Chuslin
Krasnoyarsk Scientific Research Institute of Agriculture of the Federal Research Center “Krasnoyarsk Scientific Center of Siberian Branch of Russian Academy of Sciences”, 66 Svobodny Ave., Krasnoyarsk, 660041, Russian Federation
E-mail: bogdanov-v.v@mail.ru

Abstract. The research used four varieties of barley, two varieties from the selection of the Krasnoyarsk Research Institute of Agriculture - Vulkan, Bahus and two varieties - of SibNIIRS - Acha, Biom. A four-component mixture of biotypes originally in equal proportions was composed of them. The aim of the research was to study the significance of biotypes in the formation of the productivity of artificially created mixtures and to isolate the most valuable source material for breeding work. Field assessment of biotypes was carried out in 2016-2020. in the forest-steppe zone of the Krasnoyarsk Territory. Spectra of hordeins were identified and recorded as genetic formulas (HRD A.B.F.). Changes in the biotypic composition of the studied mixture were noted already in the first year of reseeding. An increase in the proportions of two biotypes of the Novosibirsk selection 12.1.3 (1.62) and 24.8.2 (1.11) was revealed, while the proportion of biotypes of the Krasnoyarsk selection 2.25.1 and 18.67.1 decreased in equal values, amounting to (0.62), this tendency was traced throughout the entire period of the ongoing research. The differences between biotypes according to the formulas of hordeins reflects not an accidental, but a natural character, which indicates the ecological significance of the used protein markers and the importance of taking into account the variants of the spectra of hordeins when selecting parental forms and carrying out breeding work to create new varieties adapted to growing conditions. As a result of the research, two biotypes 12.1.3 (Acha), 24.8.2 (Biom) were highlighted which are of the greatest value for barley breeding as a starting material.

1. Introduction
Barley is a universal grain crop, its application is diverse. Increasing adaptation to growing conditions is an effective technique for increasing the productivity of agricultural crops, which is especially important for Eastern Siberia. For effective breeding work and the creation of new adaptive barley varieties resistant to stress biotic and abiotic factors it is necessary to have genetically diverse well-studied initial breeding material and select parental forms for crossing with local varieties [1,2].

Soil and climatic conditions have a significant impact on the formation of productivity. The factors limiting the formation of stable harvests are: a short growing season, uneven heat and moisture supply of plants, different allelic composition of barley varieties. To obtain a promising breeding material that combines high yield, grain quality and resistance to environmental factors, it is necessary to use samples of various ecological and geographical origin with improved breeding and genetic characteristics [3,4,5,6].

Genetic approaches make a significant contribution to improving the efficiency of the breeding process, shortening the time for creating new varieties while reducing the volume of field trials. The
simplest, but at the same time informative in genetic - selection studies of cereals are the storage proteins of the caryopsis, in barley they are represented by hordeins [7,8]. Evaluating breeding material based on a protein marker, it is possible to quickly and efficiently select and control the transfer of the necessary traits from parental forms to hybrid populations [9].

Purpose of the research: To study the importance of biotypes in the formation of the productivity of artificially created mixtures and to highlight the most valuable source material for breeding work.

2. Conditions, materials and methods

The experimental part of the work was carried out in the experimental fields of the Krasnoyarsk Research Institute of Agriculture, located in the central part of the Krasnoyarsk forest-steppe, in a five-year reseeding in 2015-2020. The predecessor is pure fallow, with a seeding rate of 5 million viable grains per hectare. The soil is leached chernozem. The humus content in the soil of the experimental plot is 4.3-5.2%, K2O is 14.8-17.9 mg / 100 g of soil, P2O5 is 17.6-25.6 mg / 100 g of soil. Sowing was carried out at the time optimal for this culture, May 20-25. The objects of the research were four varieties of barley, two varieties of the Krasnoyarsk Research Institute of Agriculture - Vulkan, Bahus and two varieties of SibNIIRS-Acha, Biom, of which a four-component mixture of biotypes was composed originally in equal proportions (1: 1: 1: 1). Field assessment was carried out on plots with an area of 1 m², in four replications.

Laboratory studies were carried out on the experimental base, including installations for the purification and hydrolysis of starch, devices for gel electrophoresis and the preparation of gels. Electrophoresis of barley storage proteins - hordeins (Hrd) was performed in a 13% starch gel in the presence of 3M urea in an aluminum lactate buffer at a current of 1.5 mA and a voltage of 300 V. The proteins were fixed in a 5% TCA solution for 20 min, the protein was stained with a 2% solution of water-soluble nigrosine for 30 min. [10].

The identification of the spectra of hordeins was carried out according to the catalog of blocks of components of hordeins [11] and was written in the form of genetic formulas (HRDA.B.F.).

The determination of the elements of the yield structure and their analysis was carried out by standard methods [12], statistical and mathematical processing - using the software packages Snedécor [13].

3. Results and discussion

To study the ecological role of individual biotypes, their significance in the formation of the productivity of artificially created mixtures, four varieties of barley from two Siberian regions with different genetic formulas of hordeins (Hrd) were selected, the characteristics are presented (Table 1).

| Variety | Ratio (in shares) of biotypes in mixtures | Origin | Creation region | Hordein formula (HrdABF) |
|---------|------------------------------------------|--------|----------------|-------------------------|
| Vulkan  | Created by the method of haploidy from (Dina × Risk)× Hordeumbulbosum | Krasnoyarsk region | 18.67.1 |
| Bahus   | (Viner × Donetsky 650) × (Viner × Krasnoufimsky95) | Krasnoyarsk region | 2.25.1 |
| Acha    | (Paragon ×Kristina) × [(Djet × Obskoi) × (Novosibisky 1 × Viner)] | Novosibisk region | 12.1.3 |
| Biom    | Temp × Mamlyuk | Novosibisk region | 24.8.2 |
Using selected varieties of spring barley, the four-component mixture was compiled in equal proportions (1: 1: 1: 1), which was used for five-year sowing in experimental fields of the Krasnoyarsk Research Institute of Agriculture and further study in laboratory conditions according to the spectra of storage proteins - hordeins (Table 2).

| Variety | Hordein formula (HrdABF) | Ratio (in shares) of biotypes in mixtures |
|---------|--------------------------|------------------------------------------|
|         |                          | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| Acha    | 12.1.3                   | 1    | 1.62 | 1.84 | 1.74 | 2.47 | 2.16 |
| Biom    | 24.8.2                   | 1    | 1.11 | 1.20 | 0.97 | 0.98 | 1.42 |
| Bahus   | 2.25.1                   | 1    | 0.62 | 0.40 | 0.45 | 0.38 | 0.17 |
| Vulkan  | 18.67.1                  | 1    | 0.62 | 0.56 | 0.84 | 0.13 | 0.25 |

The study of the allelic composition in the obtained crops was carried out every year for five years. For the study, caryopses were used, in which the formulas of hordeins were determined by electrophoresis. 500 germinating grains were selected from the remaining seed material for further sowing and subsequent study of the obtained crop.

The results of the five-year reseeding of the four-component mixture with initially equal representation of all biotypes are presented in the graph (Figure 1).

![Figure 1. Dynamics of the ratio (in shares) of biotypes for hordeins in a four-component mixture during their long-term reseeding.](image)

Changes in the biotypic composition of the studied mixture occurred already in the first year of reseeding; the proportion of two biotypes of the Novosibirsk selection 12.1.3 (1.62) and 24.8.2 (1.11) increased, while the proportion of two biotypes of comparison of the Krasnoyarsk selection 2.25.1 and 18.67.1 decreased in equal values reaching (0.62). As shown in Figure 1, the tendency to change the biotypic composition continued during the five-year reseeding. The maximum value - 2.47 - the share of biotype 12.1.3, reached in 2019, which was obtained due to the decrease in the share of biotype 18.67.1. Biotype 24.8.2 in all the years of the research retained its initial positions (its share fluctuated around 1.0). In 2020, an increase in its share (1.42) was noted due to a decrease in the share of biotype 2.25.1.

The productivity of a plant is a complex trait and depends on the elements of productivity. Maximum productivity is formed with an optimal ratio of all elements of its structure. Low development of one of the elements of productivity can be replenished with other elements [14].

During a five-year reseeding of biotypes, the yield and elements of the harvest structure were studied. When comparing the productivity of individual biotypes by year, it was noted that the values of this
indicator can remain high from year to year or, on the contrary, stably low. Thus, biotype 12.1.3, when calculated on average over 5 years, turned out to be the most productive (565 g/m²). At the same time, during the study period in 2016, 2019, 2020, it formed reliably the highest yield according to the experience (764 g/m², 637 g/m², 549 g/m²), respectively. The second leading biotype 24.8.2 (557 g/m²) is slightly inferior to it in terms of yield. Biotypes 18.67.1 and 2.25.1 with an average yield over five years of 393 and 349 g/m², respectively, were different from the leading biotypes in stably significantly lower yields (Table 3).

### Table 3. Characteristics of productivity elements of barley mixtures in terms of yield at standard moisture and 100% purity during the five-year reseeding period 2016-2020.

| Variety | Hrd A.B.F | Harvest at standard moisture and 100% purity, g/m² |
|---------|-----------|--------------------------------------------------|
| Acha    | 12.1.3    | 764 401 268 637 549 565                         |
| Biom    | 24.8.2    | 715 434 437 579 436 557                         |
| Vulkan  | 18.67.1   | 610 322 248 468 269 393                         |
| Bahus   | 2.25.1    | 634 238 144 277 238 349                         |
| Mixture1: 1:1:1 | 24.8.2 | 758 425 308 614 484 542 |
|         | 18.67.1   |                                                  |
|         | 2.25.1    |                                                  |

LSD 5% 121 84 145 105 132 134

*reliable differences between biotypes of varieties (lines).

At the same time the number of productive stems per 1 m² in biotypes 12.1.3. and 24.8.2 was relatively equal over the years, except for 2017, in which there was a decrease in all studied biotypes, which occurred under the influence of weather conditions. Spring moisture reserves in the soil were low. Precipitation in the second and third decades of May and the first and second decades of June was insignificant. Combined with the increased temperature in June (5°C above normal), this led to a significant decrease in yields. It should be noted that the number of productive stems in biotypes of barley from the Krasnoyarsk selection on average exceeds their number in comparison with biotypes of the Novosibirsk selection - 781 and 951 pcs/m² for biotypes 18.67.1 and 2.25.1, respectively (Table 4).

### Table 4. Characteristics of productivity elements of barley mixtures by the number of productive stems during the five-year reseeding period 2016-2020.

| Variety | Hrd A.B.F | Number of productive stems, pcs./m² |
|---------|-----------|------------------------------------|
| Acha    | 12.1.3    | 1003 312 661 773 740 748           |
| Biom    | 24.8.2    | 979 277 885 813 496 746            |
| Vulkan  | 18.67.1   | 1101 299 656 995 563 781           |
| Bahus   | 2.25.1    | 1575 293 741 867 852 951           |
| Mixture1: 1:1:1 | 24.8.2 | 920 373 848 888 917 865 |
|         | 18.67.1   |                                                   |
|         | 2.25.1    |                                                   |
|         | 12.1.3    |                                                   |

LSD 5% 449 246 204 273 386 192

*reliable differences between biotypes of varieties (lines).

b reliable differences between biotypes and 4-biotype mixture
Productive tillering capacity has an important role in the formation of the yield of spring barley. It can increase the density of the productive plant in case of stand sowing spareness. The tillering coefficient for biotypes had average experimental values, slightly higher in biotype 24.8.2 (2.13 versus 1.84 in biotype 12.1.3), and the productive tillering capacity of biotypes of comparison 18.67.1 and 2.25.1 differed upward and amounted to 2.27 and 2.22, respectively (table 5).

Table 5. Characteristics of productivity elements of barley mixtures in terms of productive tillering capacity during the five-year reseeding period 2016-2020.

| Variety | Hrd A.B.F | 2016 | 2017 | 2018 | 2019 | 2020 | average |
|---------|---------|------|------|------|------|------|---------|
| Acha    | 12.1.3  | 1.8  | 1.84 | 2.01 | 1.69 | 1.87 | 1.84<sup>b</sup> |
| Biom    | 24.8.2  | 2.4  | 2.05 | 2.30 | 1.91 | 1.99 | 2.13<sup>a</sup> |
| Vulkan  | 18.67.1 | 29<sup>a,b</sup> | 1.99 | 2.16 | 2.18 | 2.13 | 2.27<sup>a</sup> |
| Bahus   | 2.25.1  | 2.3  | 2.50<sup>a</sup> | 1.86 | 1.98 | 2.45<sup>a</sup> | 2.22<sup>a</sup> |
| Mixture | 1:1:1:1 | 2.10 | 2.04 | 2.14 | 2.10 | 2.19 | 2.11 |

LSD5% 0.72 0.59 0.48 0.52 0.58 0.26

<sup>a</sup>reliable differences between biotypes of varieties (lines).
<sup>b</sup>reliable differences between biotypes and 4-biotype mixture.

The weight of 1000 grains is of great economic importance and affects the formation of the productivity of the variety. It shows the amount of a substance contained in the grain. Its size depends on the genotype of the variety, agroclimatic conditions, the level of mineral nutrition. It is an important indicator for selection for the yield. Biotype 24.8.2 (50.2 g) occupies the leading position by the weight of 1000 grains, the second place belongs to biotypes 12.1.3, 18.67.1 reaching (45.8 g). The low weight of 1000 grains is characteristic of biotype 2.25.1 (40.7 g) (table 6).

Table 6. Characteristics of productivity elements of barley mixtures by weight of 1000 grains during the five-year reseeding period 2016-2020.

| Variety | Hrd A.B.F | 2016 | 2017 | 2018 | 2019 | 2020 | average |
|---------|---------|------|------|------|------|------|---------|
| Acha    | 12.1.3  | 47.9 | 44.5 | 43.8 | 43.4 | 48.5 | 45.8 |
| Biom    | 24.8.2  | 52.0<sup>a,b</sup> | 48.1<sup>a,b</sup> | 49.7<sup>a,b</sup> | 49.2<sup>a</sup> | 51.7<sup>a,b</sup> | 50.2<sup>a,b</sup> |
| Vulkan  | 18.67.1 | 48.7 | 43.0<sup>b</sup> | 40.9 | 45.6<sup>a,b</sup> | 50.8<sup>b</sup> | 45.8 |
| Bahus   | 2.25.1  | 42.9<sup>a,b</sup> | 38.1<sup>a,b</sup> | 37.8<sup>a,b</sup> | 39.2<sup>a,b</sup> | 45.8<sup>a</sup> | 40.7<sup>a,b</sup> |
| Mixture | 1:1:1:1 | 47.1 | 42.5 | 42.2 | 42.7 | 47.1 | 44.3 |

LSD 5% 1.95 1.78 3.92 2.87 2.49 2.19

<sup>a</sup>reliable differences between biotypes of varieties (lines).
<sup>b</sup>reliable differences between biotypes and 4-biotype mixture.

4. Conclusions
As a result of a five-year reseeding of the four-component mixture with initially equal presence of all biotypes, two biotypes 12.1.3 (Acha), 24.8.2 (Biome) were highlighted. They showed the best results and are a valuable starting material that can be used for breeding work when creating adaptive barley varieties. The identification of the allelic composition of hordeins is an effective tool for the analysis and management of the genetic structure.
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