Evaluation of the adaptability of dry bean varieties grown under conditions of organic farming

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Abstract. The acceleration of the process of import substitution is becoming a crucial issue in contemporary Russia and priority areas of such process are identified in plant breeding and seed production. A hot topic in the breeding of beans consists in creation of highly productive varieties with stable productivity. Field experiments were conducted at the Omsk State Agrarian University in 2014-2018 in order to evaluate the adaptation properties of prominent varieties of dry beans in terms of yielding capacity. All sorts were grown using the methods of organic farming, without application of pesticides and fertilizers, which allowed for an accurate evaluation of their biological productivity. The parameters of stability and plasticity of the genotypes under study were calculated following the methods of regression analysis (Eberhart, Russell, 1966). The associated trait of the studied feature in dry beans is mainly influenced by “environmental factors” (75%), to a lesser degree by the correlation “genotype x environment” (17%) and by “genotype” (7%). Based on the evaluation of the adaptation capacity and stability of the genotypes of common beans, samples with a high responsiveness to the improvement of cultivation conditions (Omichka, Luker’ya, Sizaya, Shokoladnitsa, Olivkovaya and Omskaya yubileinaya) and with a high genotype stability (Biichanka, Sibakovskaya-100, Rubin, Nerussa, Petukh) have been identified.

1. Introduction
At a global level, the process of intensive biologization of farming and crop research while reducing the environmental footprint on the biosphere by means of minimization of tillage and chemical treatment is likely to continue. In this regard, an overall increase in the area cultivated with leguminous crops, the broadening of their range, as well as the introduction of new varieties into production are needed [1–3]. The broadening of the range and cultivation area of such crops in Siberia can occur only after the identification and spreading of new adapted varieties. In the development of the domestic production of vegetable protein-containing commodities, a key role is played by common beans (Phaseolus vulgaris L.), a rich source of vegetable proteins, carbohydrates, vitamins of the B group, potassium, phosphorus, magnesium, iron and fibres. Under the conditions of the southern forest-steppe of Western Siberia, the shortage of proteins can be supplied by means of cultivation of this specific crop [3]. New varieties should not only be just as viable as their foreign analogues, but superior to them concerning essential parameters, as this might help solve the problem of import substitution of agricultural commodities [4–6].

Increasing the yielding potential is always a crucial task in breeding programs, yet innovative varieties should be not only high yielding sources of high quality commodities, but also resistant to
environmental adversities, i.e. highly adaptive and highly homeostatic. Only a high varietal adaptability (based on the homeostaticity of its genotype) can guarantee the stability of yield under different ecological conditions [7–9].

The importance of the correlation between the genotype and the environment can be found in national programs of varietal evaluation and breeding for various crops [10, 11]. The application of different parametric and non-parametric or one-factor and multidimensional methods allows for the identification of stable and plastic genotypes [12–14]. Breeding for an increase in homeostasis is particularly important in regions with an unsatisfactory humidification such as the southern forest-steppe and steppe of Western Siberia [15]. Stability is a crucial characteristic for varieties grown following the principles of organic farming [16, 17].

However, general, climatic and edaphic conditions can vary consistently even within a single region, therefore a good variety should efficiently sustain a whole range of negative factors. This very capacity of a variety to produce a consistent high quality yield under different soil, climatic, meteorological and agrotechnical conditions is called ecological plasticity [18]. Nevertheless, the execution of varietal change does not lead to an increase of yield in all regions. This is mainly due to the fact that the potential of new varieties even under optimal conditions is actualised only by 50-60% as a consequence of a relatively low adaptability in the varieties obtained, which might instead lead to a high and stable productivity under different environmental conditions.

The correlation between genotype and environment is the main reason because of which, in different years and/or locations, varieties differ as far as the yield level is concerned, since different genotypes react differently to the same environment, while single genotypes react differently to different environments. Most studies have shown significant differences in the contribution of genotypic and environmental changes to the overall phenotypic diversification of the yielding capacity and the main economically valuable parameters depending on the following conditions: year, location, agricultural background and sowing time [19].

An increase in the stability of the yield and of its structure is typical of varieties with high homeostaticity. Breeding for high homeostaticity is of capital importance, since the high adaptability of a variety can guarantee yield stability under different ecological conditions [20–23].

According to Balashova et al. [24], one of the main tasks in the breeding of leguminous crops is stabilizing the seed yield. The authors state that this issue can be solved by changing the idiotype of the plants. According to them, one of the reasons for the decrease in the yielding capacity of seeds is represented by excessive heightening and distribution of the plants. This is due to the fact that some varieties continue their vegetative growth even after the formation of reproductive organs, especially under moist climatic conditions. Consequently, breeders’ attempts should be focused on changes in the plant habitat and on the development of highly productive determinate forms.

In 2019, 25 new varieties of dry beans were approved by the State Register of Breeding Achievements of the Russian Federation, thus certain improvements in the creation of varieties with different levels of adaptation aimed at the formation of high quality seeds could be observed.

The aim of the present research is to evaluate prominent dry bean varieties as regards their main environmental parameters, as well as productivity, adaptation capacity and ecological plasticity.

2. Materials and methods
The varietal evaluation of the common bean collection was carried out in terms of collection nursery of breeding crop rotation at the Training and Experimental Farm of Omsk State Agrarian University in cooperation with the Shared Use Centre “Breeding and Seed Production of Field Crops” over a period of 5 years (2014-2018). The soil type is meadow-chernozem with average fertility, low humus and high loam content.

Object of the research were collection samples of common beans (121 samples) with different origin. The forecrop in the crop rotation was spring wheat. The variety Biichanka was used as a control sample. Samples were sown on plots with a surface of 5.2 m². The replication was threefold. The plants were grown applying the methods of organic farming without using fertilizers or pesticides. The trials were
laid following the Methods for State Varietal Evaluation of Agricultural Crops (Moscow, 1989) and the Methods of the All-Russian Institute of Plant Industry (Methodical Guidelines, 1987). The obtained data were elaborated using a two-factor dispersion analysis for each feature in order to determine the impact of the genotypes (of the samples) (G), of the environment (E) and of their correlation (G × E). The evaluation of the ecological plasticity was performed by applying regression analysis following the method by S.A. Eberhart and W.A. Russel (1966) in 12 prominent samples of dry beans with a set of valuable features under the conditions of the southern forest-steppe of Western Siberia.

3. Results and discussion

The environmental conditions varied over the years of the research on collection samples: 2017 and 2018 were arid (HTC of 0.72 and 0.90, respectively), 2014 and 2015 were semi-arid (HTC of 1.18 and 1.22), and 2016 was wet (HTC of 1.35).

To prove the presence or absence of a correlation between the whole set of genotypes under study and the environment, the model of two-factor dispersion analysis was applied. The dispersion analysis showed that weather conditions have a dominating impact (75%) on the productivity of dry bean plants under the conditions of the Omsk Region. The impact of the genotype was significant as well (7%), which proves the presence of substantial differences between the set of samples under study concerning the yielding capacity and the correlation “genotype x environment” (17%), as shown in Figure 1. The statistical significance of the factors of genotype, conditions and their correlation was an objective precondition for determining the adaptability parameters for almost all features.

![Figure 1. Impact of the factors on the productivity of seeds in the prominent samples of dry beans (2014-2018), %](image)

According to the degree of their reaction to changes in the environmental conditions, prominent samples from the dry bean collection were divided into three groups.

Of practical interest is a group of samples with a fairly high yielding capacity and responsiveness to the cultivation conditions (bi > or = 1); the group includes the varieties Luker’ya, Sizaya, Omskaya yubileinaya, Omichka, Olivkovaya and Shokoladnitsa.

Particularly valuable are also those samples with an average to high yielding capacity, a regression coefficient (bi) close or superior to 1, a stability (σd2) close to 0, thus with a complete responsiveness of the variety yielding capacity to changes in the cultivation conditions. Among the studied varieties, this group includes Omskaya rannyaya, Omskaya yubileinaya and Nerussa.

The third group includes the samples Biichanka, Sibakovskaya-100, Rubin, Nerussa and Petukh, with a relatively low average yielding capacity, a weak reaction to improvement in the environmental conditions (bi < 1) and high yield stability.

It is not possible to give a full and reliable variety evaluation based only on the value of the regression coefficient (bi). It is because with such high values of responsiveness to the improvement of the conditions, varieties can be characterised by a low yield stability over the years and by its low degree, which has a negative result for their practical significance. The index of aberration from the regression line or level of reaction stability (σd2) is an important parameter in the comprehensive evaluation of genotypes in the research process. On average over the period 2014-2018, the following samples were
characterized by a high reaction as regards the stability degree: Omichka, Sizaya, Omskaya yubileinaya, Sibakovskaya-100, Rubin and Nerussa. A low stability degree was observed in the samples Biichanka, Olivkovaya and Petukh.

An information chart on the reaction of varieties to the environmental conditions is given by the lines of yield regression according to changes in the cultivation conditions (Figure 2). The regression lines provide for two crucial characteristics of the varieties: the value of their average yield in comparison with the average of the whole set of varieties under study and the degree of their reaction to changes in the cultivation conditions, which is characterised by the inclination of the regression line itself. Of practical interest are those varieties with regression lines which have a positive slope in the right part of the chart (favourable conditions) – thus with a high responsiveness to an improvement in the environmental conditions – and a slightly negative slope in the left part (rough conditions) – thus with a high buffering capacity of the genotypes under unfavourable cultivation conditions. In addition, such varieties should be characterised by a high average yield. To a higher or lower extent, such requirements are met by varieties which are characterised by a fairly high yielding capacity and responsiveness to cultivation conditions (bi ≥ 1) such as Luker’ya, Sizaya, Omskaya yubileinaya, Omichka, Shokoladnitsa and Olivkovaya; this type of reaction is characteristic of intensive-type samples.

The variety Olivkovaya is the best one in the set. It is characterised by a high responsiveness to the improvement of the cultivation conditions, as shown by the regression line. Under rough conditions, its yielding capacity is higher if compared to other varieties in the set; in addition, it shows the highest average yield if compared to the other varieties.

Table 1. Parameters of ecological plasticity of the yield in the prominent collection samples of dry beans, 2014-2018

| N. | Factor A (variety) | Factor B (year) | Average | bi | σ^2 |
|---|-------------------|-----------------|---------|----|-----|
|   |                   | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|-------------------|------|------|------|------|------|
| 1 | Omichka (control sample) | 0.40 | 0.39 | 0.54 | 0.61 | 0.48 | 0.48 | 1.05 | 0.004 |
| 2 | Omskaya rannyaya | 0.10 | 0.12 | 0.18 | 0.35 | 0.32 | 0.21 | 1.00 | 0.011 |
|   |                   | Mid-early varieties |
| 1 | Biichanka (control sample) | 0.19 | 0.17 | 0.16 | 0.27 | 0.23 | 0.20 | 0.25 | 0.263 |
| 2 | Olivkovaya | 0.49 | 1.50 | 0.67 | 0.48 | 0.45 | 0.72 | 0.50 | 0.079 |
| 3 | Luker’ya | 0.33 | 0.48 | 1.10 | 0.78 | 0.31 | 0.60 | 3.26 | 0.018 |
| 4 | Sizaya | 0.37 | 0.36 | 0.68 | 0.82 | 0.57 | 0.56 | 2.25 | 0.014 |
| 5 | Omskaya yubileinaya | 0.30 | 0.32 | 0.31 | 0.59 | 0.47 | 0.40 | 1.09 | 0.010 |
| 6 | Sibakovskaya-100 | 0.57 | 0.62 | 0.51 | 0.47 | 0.39 | 0.51 | -0.35 | 0.013 |
| 7 | Rubin | 0.22 | 0.14 | 0.39 | 0.34 | 0.38 | 0.29 | 0.64 | 0.003 |
| 8 | Nerussa | 0.13 | 0.32 | 0.21 | 0.32 | 0.20 | 0.23 | 0.91 | 0.0004 |
| 9 | Petukh | 0.30 | 0.28 | 0.29 | 0.32 | 0.27 | 0.29 | 0.09 | 0.038 |
|   |                   | Mid-season varieties |
| 1 | Shokoladnitsa (control sample) | 0.33 | 0.36 | 0.39 | 0.70 | 0.72 | 0.50 | 1.32 | 0.011 |
|   | Average | 0.31 | 0.42 | 0.45 | 0.50 | 0.39 | – | – | – |
|   | LSD_{0.05} | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | – | – | – |
|   | I_j | –0.11 | 0.00 | 0.03 | 0.09 | –0.02 | – | – | – |
|   |                   | Full-season varieties |
Based on the evaluation of the adaptation capacity and stability of the genotypes of common beans under changing environmental conditions, the following samples distinguished themselves for their high responsiveness to an improvement in the cultivation conditions: Omichka, Luker'ya, Sizaya, Shokoladnitsa, Olivkovaya and Omskaya yubileinaya; for their low responsiveness: Biichanka, Sibakovskaya-100, Rubin, Nerussa and Petukh. Pre-existing reactions of the varieties to changes in the cultivation conditions allow for a further scientifically grounded planning of trials, disposing varieties with a high responsiveness to an improvement in the habitat on high agricultural backgrounds in more favourable soil and climatic areas and varieties with a low responsiveness in unfavourable ones.

![Figure 2. Regression lines of the yield of dry bean samples, 2014-2018](image)

4. Conclusion
The associated trait of yield in dry beans is mainly influenced by “environmental factors” (75%), at a lesser extent by the correlation “genotype x environment” (17%) and “genotype” (7%). Based on the evaluation of the adaptation capacity and stability of the genotypes of common beans under changing environmental conditions, the following samples distinguished themselves for their high responsiveness to an improvement in the cultivation conditions: Omichka, Luker'ya, Sizaya, Shokoladnitsa, Olivkovaya.
and Omskaya yubileinaya; for their low responsiveness: Biichanka, Sibakovskaya-100, Rubin, Nerussa and Petukh. Pre-existing reactions of the varieties to changes in the cultivation conditions allow for a further scientifically grounded planning of trials, disposing varieties with a high responsiveness to improvement in the habitat against high agricultural backgrounds in more favourable soil and climatic areas and varieties with a low responsiveness in unfavourable ones.

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