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# ADAPTABILITY OF CHICKPEA COLLECTION SAMPLES IN THE SOUTHERN FOREST-STEPPE OF WESTERN SIBERIA

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## Abstract

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The recognized chickpea varieties do not fully meet the requirements of modern agriculture. This necessitates creation of new highly adapted chickpea varieties of an intensive type, suitable for cultivation both in the regions of traditional chickpea cultivation and in promising, non-traditional areas. This paper contains a comparative assessment of chickpea collection samples in terms of their economically useful characteristics, as well as the ecological plasticity evaluation of 13 chickpea samples developed under the conditions of southern forest-steppe of Western Siberia; the evaluation was done on the basis of the plant grain productivity. The study has revealed the chickpea varieties that can become sources of certain economically valuable characteristics: Line C-82, C4-Deemin, C7-Alexandrite, C14-Alexandrite, C17-C11– reduction of the growing season; ILC-10005, Volgogradsky 10, C4-Deemin – reduction of the plant height; C1-Alexandrite, Volgogradsky 10, C2-Krasnokutsky 123 – increase in the number of seeds per plant; C2-Krasnokutsky 123, C-243, ILC-482, C13-Deemin – increase in the weight of seeds per plant. The obtained data show that in the forest-steppe of Western Siberia, weather conditions had the greatest impact on the productivity of chickpea plants (their impact share reaches 92.1%). The calculation of ecological plasticity parameters revealed samples characterized by high ecological plasticity and responsiveness to growing conditions: C-82, C3-5, C1-Alexandrite, C5-Krasnokutsky 123, C15-Volgogradsky 10, C4-Deemin, as well as samples characterized by high yielding stability: C-18, C-80, Krasnokutsky 123, C3-Alexandrite, C6-Alexandrite, C16-Krasnokutsky 123, C11-Yubileiny.

*Key words:* chickpeas; adaptability; ecological flexibility; productivity; sample

## Introduction

The problem of protein deficiency in the nutrition of humans and domestic animals attracts special attention to the production of vegetable protein, an important source of which is grain legumes (Strategiya razvitiya, 2010).

Legumes belong to essential foods due to a high content of easily digestible protein, vitamins, biologically active substances and mineral salts. Due to their high nutritional value, legumes are recognized to be a part of the "healthy food", have an enormous biological resource potential and occupy a leading place in the development of the third-generation food technologies, which provide thorough processing of raw materials and regulate the chemical composition according to the criteria of nutritional and biological value (Polyudina et al., 2002; Rozhanskaya et al., 2002; Kuzmina et al., 2014). It is quite likely that in the near future, human nutrition will be improved thanks to the widespread use of foods rich in vegetable protein. Analysts say that in the XXI century, the process of intensive biologization of farming and crop production will continue through reducing the anthropogenic impact on the biosphere by minimizing tillage and decreasing the use of chemicals. The share of legumes in the structure of sown areas of Western Siberia is only 1 to 2%, which is clearly insufficient. Moreover, in spite the legume family is very diverse; the farms of the Siberian region

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cultivate mainly peas (Kuzmina et al., 2016; Kazydub and Kuzmina, 2016).

In this connection, it is necessary to increase the total area for legumes, expand their product range, as well as introduce new, non-traditional legumes, including chickpeas. In Siberia, expansion of the range and cultivation area of legumes is possible only after breeding and distribution of new well-adapted varieties (Zhuchenko, 2003; Kazydub et al., 2015; Kazydub et al., 2016).

Chickpea is drought-resistant, feasible for harvesting, and resistant to diseases and pests; it has high nutritional value and can be utilized for various food purposes. Thus, its cultivation can significantly stabilize the production of high-protein grain and increase the general stability of agricultural systems. Chickpea pulse contains plenty of phosphorus, potassium and magnesium; it is also a source of lecithin, riboflavin, thiamine, nicotinic and pantothenic acids, choline. The content of Vitamin C in the chickpea pulse ranges from 2.2 to 20 mg per 100 g of biomass. It was found that chickpea leaves contain oxalic, citric and malic acid. In terms of fat content, chickpeas surpass other legumes (except soy); the amount of this indicator depends on the variety and ranges from 4.1 to 7.2% (Rozhanskaya, 2002; Vasyakin, 2002; Bulyntsev, 2003; Vishnyakova, 2007).

In the conditions of unpredictable fluctuations in weather, breeders' efforts should be aimed at creating ecologically plastic varieties that provide objectively high yields in favorable cultivation conditions and do not reduce yields under stress. To determine ecological stability, researchers often use the technique proposed by S. A. Eberhart and W. A. Russell; it allows defining both the plasticity and stability of genotypes. This technique is based on the calculation of the linear regression coefficient (bi) characterizing the ecological plasticity of a variety, and the standard deviation from the regression line ($\sigma_d^2$) determining the variety stability under different environmental conditions (Zykin et al., 2008).

Studies of chickpea ecological plasticity for southern Western Siberia are very important due to the unstable climate factors of the area. Changes of weather conditions, as well as lacking balance between the adaptive capacities of the utilized varieties lead to abrupt fluctuations in the yield of the recommended chickpea varieties.

An increase in chickpea pulse production is associated with creation of new chickpea varieties that are well adapted to the difficult conditions of the region, as well as with an increase in sowing early-ripening varieties. A collection of chickpea samples from different eco-climatic zones can serve as a source material for creating such varieties.

The aim of this study was comparative evaluation of collected chickpea samples in terms their economically valuable characteristics, and calculation of their ecological plasticity parameters.

## Materials and Methods

The experimental part of the study was carried out in 2012-2015, on the experimental fields of Omsk State Agrarian University, which are located in the southern forest-steppe of Omsk region (Russia). Southern forest-steppe is characterized by warm, moderately wet climate. The total amount of average daily temperatures for the period with a temperature above 10° is about 100-130 days. The frost-free period in this area is 110-120 days on the average; the period with a temperature above 0°C is 185 days, above 5°C – 157 days, above 10°C – 123 days. Night frosts in the air in spring cease on May 21-22 and resume in autumn – in September 10-22. Plenty of sunlight and warmth sufficiently compensates for the short duration of the frost-free period and ensures plant vegetation. The southern forest-steppe of Omsk region is a zone of unstable humidification. The average long-term annual precipitation is 300-350 mm; the precipitation for the period with stable average daily air temperature above 10° is 190-220 mm. The region's supply of plant moisture is characterized by the hydrothermal coefficient 1.0-1.2, which points to a quite satisfactory level of moisture during active vegetation. By the time of planting, the soil moisture reserves are usually sufficient. The soil of the experimental field is common moderate-fertile medium-humus black soil.

The objects of the research were 46 collection chickpea samples (23 samples from N. Vavilov Institute of Plant Genetic Resources (VIR, St. Petersburg) and 23 self-cloning samples from Siberian Research Institute of Feedstuff (Novosibirsk)). The reference cultivar was the variety Krasnokutsky 123.

Sowing was carried out manually to a depth of 5 cm, according to the scheme 60x10 cm. There were 3 trials. The number of seeds in each trial was 30. All observations, records and analyzes were performed according to the "Guidelines for the study of a grain legumes collection" (Metodicheskie ukazaniya, 1975; Vishnyakova, 2010). The calculation of the plasticity and stability indexes of the samples was performed by the method of S. A. Eberhart and W. A. Russel (Zykin et al., 2008).

## Results and Discussion

The years 2012 and 2014 were very dry (the hydrothermal moistening coefficient (HMC) was 0.54 and 0.60 respectively). The years 2013 and 2015 were low-dry (with HMC of 1.01 and 1.02 respectively).

The duration of the growing season is very important for obtaining high yields. Its optimal duration allows a cultivar to use the soil-climatic resources of the zone in a best way, as well as to avoid the negative impact of adverse conditions to the maximum extent. In the years of the study, the shortest growing season was observed in the following samples: C4-Deemin, C7-Alexandrite, C14-Alexandrite, and C17-C11. They ripened earlier than the reference variety by an average of 5 days (see Table 1).

A compact bush form and a proper height of the lowest pod are important breeding features characterizing the suitability of chickpea cultivars for mechanized cultivation. The self-pollinations (Siberian Research Institute of Feedstuff) differed from the VIR's collection samples – the first ones had a more compact, upright bush, while the bush form of some chickpea samples from the VIR's collection was spreading and reclining. In the case of collection chickpea samples, the height of the lowest pod ranged from 8 to 40 cm. The greatest height of the lower pod attachment was observed in the samples: C11-Yubileiny, C9-A-11, C18-Krasnokutsky 123, Line C-18, ILC-248 (see Table 2).

The height of chickpea plants is directly related to seed productivity; thus, selection for yield is possible on this basis. Over the years of the experiment, the height of the chick-

**Table 1**
**Duration of the interphase development periods for the most explicit collected chickpea samples in 2012-2015, days**

| Point No. | Sample | Seeding – sprouting | Sprouting – blossoming | Blossoming – ripening | Growing season |
|---|---|---|---|---|---|
| 1 | Krasnokutsky 123 (reference) | 10 | 33 | 54 | 91 |
| 2 | LS -17 | 17 | 29 | 51 | 97 |
| 3 | ILC-10005 | 15 | 30 | 51 | 92 |
| 4 | LS-18 | 13 | 32 | 59 | 97 |
| 5 | LS-82 | 13 | 32 | 60 | 97 |
| 6 | LS-83 | 10 | 34 | 61 | 96 |
| 2 | C4-Deemin | 10 | 31 | 51 | 86 |
| 3 | C7-Alexandrite | 10 | 31 | 51 | 86 |
| 4 | C14-Alexandrite | 10 | 31 | 51 | 86 |
| 5 | C15-Volgogradsky 10 | 10 | 30 | 53 | 87 |
| 6 | C17-C11 | 10 | 31 | 51 | 86 |

**Table 2**
**Biometric indicators of the most explicit collected chickpea samples in 2012-2015**

| Point No. | Sample | Dry weight of the plant, g | The plant height, cm | The lowest pod height, cm | The number of first-order branches |
|---|---|---|---|---|---|
| 1 | Krasnokutsky 123 (reference) | 71.8 | 80.5 | 30.6 | 2.8 |
| 2 | ILC-2394 | 86.6 | 80.3 | 28.4 | 2.9 |
| 3 | ILC-2402 | 66.9 | 89.6 | 27.5 | 2.1 |
| 4 | ILC-482 | 89.5 | 86.1 | 29.1 | 2.5 |
| 5 | Line C-18 | 93.9 | 86.1 | 29.7 | 2.7 |
| 6 | Line C-35 | 73.8 | 80.3 | 28.1 | 2.1 |
| 7 | Line C-83 | 79.5 | 92.8 | 28.4 | 2.9 |
| 8 | C9-A-11 | 61.6 | 94.8 | 38.0 | 2.4 |
| 9 | C10-Kolorit | 60.7 | 90.8 | 34.5 | 2.8 |
| 10 | C11-Yubileiny | 69.2 | 93.2 | 38.2 | 2.8 |
| 11 | C14-Alexandrite | 68.3 | 83.8 | 31.9 | 3.2 |
| 12 | C18- Krasnokutsky 123 | 67.9 | 95.9 | 39.7 | 2.9 |
| 13 | C19-1-10 | 69.5 | 92.9 | 34.8 | 2.8 |
| 14 | C20-3-10 | 60.2 | 92.6 | 34.4 | 2.7 |
| 15 | C21-F-11 | 57.7 | 83.3 | 32.3 | 2.8 |
| 16 | C23-Kolorit | 56.3 | 91.5 | 36.3 | 2.5 |
|  | $LSD_{05}$ | 7.3 | 7.7 | 2.5 | 0.2 |

**Table 3**
**Productivity components of the most explicit collected chickpea samples in 2012-2015**

| Point No. | Sample | Number of pods per plant | Weight of pods per plant, g | Number of seeds per plant | Weight of seeds per plant, g |
|---|---|---|---|---|---|
| 1 | Krasnokutsky 123 (reference) | 87.2 | 34.1 | 100.6 | 26.4 |
| 2 | C-27 | 81.8 | 23.2 | 73.2 | 17.6 |
| 3 | C-243 | 104.4 | 35.9 | 84.7 | 22.7 |
| 4 | C-303 | 84.9 | 30.7 | 78.6 | 19.2 |
| 5 | C-17 | 79.3 | 21.1 | 81.3 | 23.8 |
| 6 | 22-B | 72.3 | 27.4 | 53.7 | 16.4 |
| 7 | Line C-17 | 93.9 | 31.0 | 85.6 | 16.5 |
| 8 | Line C-18 | 116.9 | 30.1 | 85.4 | 15.8 |
| 9 | C1-Alexandrite | 97.9 | 38.3 | 120.7 | 26.9 |
| 10 | C3-Alexandrite | 67.0 | 25.9 | 75.3 | 20.5 |
| 11 | C4-Deemin | 66.3 | 32.9 | 71.1 | 25.3 |
| 12 | C6-Alexandrite | 70.8 | 30.1 | 72.6 | 22.3 |
| 13 | C7-Alexandrite | 88.9 | 34.0 | 96.1 | 24.2 |
| 14 | C13-Deemin | 71.7 | 25.7 | 74.3 | 20.2 |
| 15 | C14-Alexandrite | 71.3 | 26.7 | 82.8 | 21.1 |
| 16 | C19-1-10 | 75.5 | 26.5 | 80.2 | 20.2 |
| | $LSD_{05}$ | 9.5 | 2.9 | 8.1 | 1.9 |

pea collection samples ranged from 30.2 to 161.6 cm. The greatest plant height was observed in the following chickpea samples: ILC-2394, C2-Krasnokutsky 123, C16-Krasnokutsky, C20-3-10, and C23 Kolorit.

During the experiment, the average dry plant weight of the chickpea samples varied in the range of 35.6 to 71.8 g. By the end of the growing season, the self-pollinations had a lesser foliage compared with the samples from VIR, which is connected with their earlier maturation and indicates their suitability for mechanized cultivation.

In the years of the experiment for the given conditions, the yield of the chickpea samples, as well as its components, were not high and greatly varied depending on weather conditions (Table 3).

The sources of the specific features that characterize the chickpea plants productivity in the given environment were the following chickpea collection samples: the number of pods per plant – C-243, Line C-18, Line C-17, C1-Alexandrite, C7-Alexandrite; the weight of pods per plant – C-243, Line C-18, Line C-17, C-303, C1-Alexandrite, C7-Alexandrite; the number of seeds per plant – C-243, Line C-18, Line C-17, C1- Alexandrite, C7- Alexandrite; the weight of seeds per plant – C-17, C-243, C-303, C1-Alexandrite, C7-Alexandrite, C4-Deemin.

The experimental conditions allowed us to ascertain some chickpea collection samples that are important in terms of their economically valuable characteristics: C-243, Line C-18, Line C-17, C1-Alexandrite, C7-Alexandrite.

Ecological plasticity parameters were calculated for the 13 chickpea samples that had the most explicit set of signs in the conditions of the southern forest-steppe of Western Siberia.

A bi-factor variance analysis of the data on chickpea pulse productivity (Table 4) proved the statistical signifi-

**Table 4**
**The results of the bi-factor variance analysis of grain productivity for the collection chickpea samples (2012-2015)**

| Variance | Sum of squares (SS) | Degrees of freedom (df) | Mean square (mS) | F-test | | Factor share, % |
|---|---|---|---|---|---|---|
| | | | | $F_{fact.}$ | $F_{05}$ | |
| Total | 27432.4 | 207 | – | – | – | – |
| Iteration | 57.5 | 3 | – | – | – | – |
| Varieties (A) | 2966.0 | 12 | 247.2 | 14.7* | 1.82 | 4.4 |
| Years (B) | 15449.1 | 3 | 5149.7 | 306.2* | 2.66 | 92.1 |
| Interaction (AxB) | 6386.4 | 36 | 177.4 | 10.5* | 1.18 | 3.2 |
| Remainder (error) | 2573.3 | 153 | 16.8 | – | – | 0.3 |

* Significant at $P<0.05$

**Table 5**
**Environmental plasticity of grain productivity for the chickpea collection samples (2012-2015)**

| Sample | Grain productivity per plant, g | | | | | Plasticity, bi | Stability, $\sigma_d^2$ |
|---|---|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | average | | |
| Krasnokutsky 123 (reference) | 24.2 | 27.2 | 28.4 | 21.6 | 25.3 | 0.1 | 1.4 |
| C-18 | 25.6 | 19.3 | 16.9 | 9.6 | 17.8 | 0.6 | 0.4 |
| C-35 | 29.7 | 20.1 | 11.6 | 3.1 | 16.1 | 1.1 | 0.1 |
| C-80 | 22.3 | 11.3 | 10.4 | 2.7 | 11.7 | 0.8 | 1.0 |
| C-82 | 31.5 | 16.4 | 5.5 | 1.8 | 13.8 | 1.3 | 0.9 |
| C1-Alexandrite | 37.2 | 23.8 | 21.4 | 2.2 | 21.2 | 1.4 | 3.9 |
| C3-Alexandrite | 22.5 | 26.9 | 13.7 | 5.5 | 17.2 | 0.8 | 3.6 |
| C4-Deemin | 54.5 | 19.8 | 2.6 | 7.8 | 21.2 | 2.1 | 15.3 |
| C5-Krasnokutsky 123 | 25.7 | 28.0 | 9.3 | 3.1 | 16.5 | 1.1 | 3.6 |
| C6-Alexandrite | 26.2 | 21.9 | 9.2 | 5.9 | 15.8 | 1.0 | 0.5 |
| C15-Volgogradsky 10 | 28.1 | 11.3 | 8.9 | 0.5 | 12.2 | 1.1 | 2.0 |
| C16-Krasnokutsky 123 | 19.4 | 16.1 | 10.7 | 5.7 | 13.0 | 0.6 | 0.1 |
| C11-Yubileiny | 26.7 | 27.3 | 4.7 | 10.3 | 17.2 | 1.0 | 5.7 |
| Average | 28.7 | 20.7 | 11.8 | 6.1 | 16.8 | 16.8 | – |
| Ij | 11.9 | 3.9 | -5.1 | -10.7 | – | – | – |

cance of the variances that reflect variability due to genotypic differences of the samples (A), meteorological factors (B) and their interaction (AxB). Weather conditions (B) had the greatest impact on the productivity of chickpea plants in Omsk Region (92.1%), whereas genotypic variability (A) was only 4.4% and the interaction between genotypes and conditions (AxB) was 3.2%.

A reduction of the grain productivity fluctuations occurring due to the varying agro-climatic factors of Western Siberia can be achieved by proper selection of varieties. The most favorable conditions for the growth and development of chickpea plants were observed in the warm and dry growing season of 2012 – the environment conditions index (Ij) was 11.9; the worst conditions were formed in 2015, Ij = –10.7 (Table 5).

To characterize the genotype reaction to the changes in growth conditions, we used two indicators: regression coefficient (bi) that shows a variety response to changing environmental conditions (plasticity), and the variance degree ($\sigma_d^2$) that characterizes the yield stability (stability index).

It was found that the larger the regression coefficient, the greater the cultivar response to changes in its growth conditions, and the smaller the stability variance, the more stable is the cultivar upon changes in the growing conditions. Scientists believe that the most valuable varieties (both for selection and practical use) are the varieties with plasticity (bi)>1 and insignificant stability index ($\sigma_d^2$). Along with high productivity, such varieties have a high responsiveness to improving conditions, which is specific for intensive-type varieties. Among the studied chickpea collection samples, such indicators of plasticity (bi) and stability ($\sigma_d^2$) were evident for C-35 and C-82.

The results of the studied parameters of chickpea collection samples adaptability are presented in Table 5.

The forms with high plasticity (bi) and stability index ($\sigma_d^2$) are inferior to the first ones in value, as their high responsiveness to growing conditions is combined with significant variability in productivity. Such forms include the chickpea samples C1-Alexandrite, C5-Krasnokutsky 123, C15-Volgogradsky 10, C4-Deemin; their productivity is significantly reduced in unfavorable conditions.

The varieties, the plasticity (bi) of which is significantly less than 1, should be regarded as not very promising regardless of their index stability value ($\sigma_d^2$), because they are lacking in such essential biological and economic feature as adequate response to improved growing conditions. Such a reaction is specific for the varieties of extensive type. Among the studied chickpea samples, we can mention C-18, C-80, and Krasnokutsky 123.

The graphical representation of grain productivity regression lines for collection chickpea samples on coordinate axes relatively to each other provides visual information about the response of the varieties to changing environmental conditions (Figure 1).

For breeding and agronomic practice, it is best to use the samples, the regression lines of which show high pro-

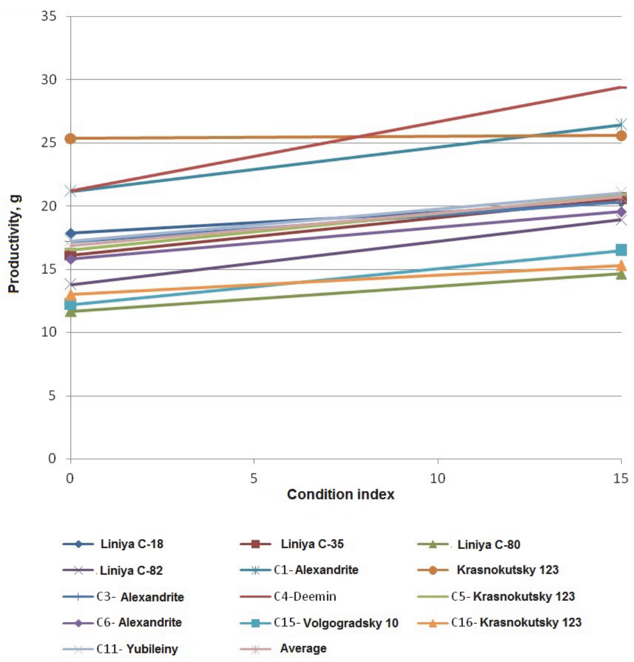


**Fig. 1. Productivity regression lines for the selected chickpea collection samples (2012-2015)**

ductivity in favorable growing conditions (that characterizes their high responsiveness to improving conditions) and which insignificantly reduce productivity in tough growing conditions (that characterizes the stability of genotypes under adverse conditions). Such samples include the following chickpea collection varieties: C4-Deemin, C1-Alexandrite. The regression lines of other samples are mostly running parallel to the experiment's average, i.e. these forms change their yield with changing conditions like the studied set of samples on average.

The results of the study of ecological plasticity give grounds to recommend the selected samples with high responsiveness to improved growing conditions and high productivity (C-35 and C-82) for hybridization in order to create chickpea cultivars that will be adapted to the conditions of the area.

## Conclusions

1. The sources of certain economically valuable characteristics can become the following chickpea samples:

- growing season reduction: Line C-82, C4-Deemin, C7-Alexandrite, C14-Alexandrite, C17-C11;
- plant height reduction: ILC-10005, Volgogradsky 10, C4-Deemin;
- increase in the number of seeds per plant: C1-Alexandrite, Volgogradsky 10, C2-Krasnokutsky 123;
- increase in the weight of seeds per plant: C2-Krasnokutsky 123, C-243, ILC-482, C13-Deemin.

2. The majority of chickpea collection samples comply with the requirements of process effectiveness and suitability for mechanized harvesting.

3. In the conditions of southern forest steppe, the productivity of chickpea plants was mainly influenced by weather conditions (the share of variation is 92.1%). The influence of genotype and the interaction of genotype and years were also statistically significant (4.4% and 3.2% correspondingly).

4. There are selected samples that are characterized by high ecological plasticity and responsiveness to growing conditions (intensive-type samples): C-82, C3-5; C1-Alexandrite, C5-Krasnokutsky 123, C15-Volgogradsky 10, C4-Deemin can also be prospective. The mentioned samples are recommended for inclusion in the selection process scheme as sources of ecological plasticity.

5. There are selected samples that are characterized by a weak response to the improvement of environmental conditions and high yield stability (extensive-type samples): C18, C80, Krasnokutsky 123, C3-Alexandrite, C6-Alexandrite, C16-Krasnokutsky 123, C11-Yubileiny.

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