Assessment of ecological properties of winter wheat seeds

V I Pushkareva¹, G G Goleva¹, T G Vashchenko¹, T P Fedulova², A D Golev³ and V A Ivannikov³

¹ Voronezh SAU, 1, Michurina st, Voronezh, 394087, Russia
² A Mazlumov Al-Russian Research Institute of Sugar Beet and Sugar, 86, Ramon District, Voronezh Oblast, VNIISS, 396030, Russia
³ Morozov VSUFT, 8, Timiryazeva st, Voronezh, 394087, Russia

E-mail: golevavetryak@yandex.ru

Abstract. Seed quality is one of the essential prerequisite for high yield formation. Ecological heterogeneity of seeds remains one of the unsolved challenges of seed production as yet. The existence of close relation between seed quality and the conditions of their growing indicates the relevance of the assessment of the ecological nature of seed heterogeneity and becomes the target of the authors’ study. Laboratory and field methods were widely used. The authors investigated different fractions of winter wheat seeds of the Alaya Zarya variety. The seeds were calibrated by width, by the specific weight, and by thickness. The studies have shown that seeds of different fractions differ in their ecological properties. Large seeds calibrated by width, seeds of low specific weight and seeds of shallow thickness were characterized by high responsiveness to vegetation conditions. The seeds of these fractions are recommended to be used in intensive cultivation technologies. The seeds of large fraction calibrated by thickness were characterized by high homeostatic properties and are recommended to be used in organic farming.

1. Introduction
Seed production is of great importance for preserving genetic properties of the variety. Each seed is characterized by biological properties, distinctness, so, naturally, the seeds are heterogeneous. Seed heterogeneity can be associated with genetic, maternal or environmental factors. At that, genetic heterogeneity is transmitted by heredity to the entire progeny; maternal heterogeneity is the result of different location and time of seed formation on the maternal plant; environmental heterogeneity is due to the influence of environmental conditions on the seeds resulting in the differences in their chemical composition, morphological and physiological properties. All the forms of heterogeneity are responsible for morphological differences of seeds of one lot by weight, shape, size, degree of plumpness, chemical composition, as well as for physiological, biological and genetic characteristics [1].

Seed quality is one of the essential prerequisite for high yield formation. The mass of grain is determined not only by its size, but also by the structure and density. Therefore, calibration of seeds before sowing is accepted in agricultural practice throughout the world, and calibration is carried out not only by size, but also by specific weight [2].

The ecological heterogeneity of seeds remains one of the unsolved challenges of seed production as yet. The conditions of the growing season cause the changes in the seeds affecting the functioning of
the plant organism as a whole. This is the result of the interaction of the genotype with the environment [3, 4]. The existence of close relation between seed quality and the conditions of their growing indicates the relevance of the assessment of the ecological nature of seed heterogeneity and becomes the target of the authors’ study.

To assess ecological properties of varieties, their study is carried out at different ecological points or in a single one, but with different preceding crops, at different sowing times, etc. [5]. According to S. Filipenko [6], a set of factors, i.e. sowing dates, preceding crops, protective measures (such as combinations of seed treatment, fungicidal and herbicidal treatment), used in one geographical point allows predicting the behavior of genotypes in other regions with high reliability. The authors used similar approach to assess the adaptive properties of winter wheat seeds of different fractions.

2. Materials and methods
The experimental part of the study was performed in 2015–2018 in field trials of the Department of Plant and Seed Breeding, and Biotechnologies of Voronezh State Agrarian University named after Emperor Peter the Great in the conditions of the forest steppe of the Central Chernozem Region of the Russian Federation.

The authors prepared three fractions of winter wheat seeds of the Alaya Zarya variety. The fractions were obtained by calibration:

(i) by width using sieve separator (Variant SS 2.2 means screenings from sieves, the size of holes is 2.2×30 mm; Variant SS 2.5 means screenings from sieves, the size of holes is 2.5×30 mm; Variant SS 3.0 means screenings from sieves, the size of holes is 3.0×3.0 mm);

(ii) by thickness using an experimental sample of the modified air separator without sieves (Variants AS 1, AS 2, AS 3, AS 4) [7];

(iii) by specific weight (density) using the SAD-4 aerodynamic separator (Variants SAD 2, SAD 3).

Uncalibrated seeds were used as the control variant (C).

Sowing of winter wheat was carried out in three terms with an interval of 10 days, starting from the first decade of September.

Agricultural technology is generally accepted in the Central Chernozem Region of the Russian Federation. The experiment was laid in 3 replicates with the randomized location of the plots. The area of the registration plot was 2 m$^2$. All records and observations were made according to the conventional methodology. Statistical data analysis was performed using Statistica 6.1 software package.

3. Characteristics of seed fractions by weight of 1000 grains and evenness
It is known that for the formation of friendly sprouts and their further even development, the seeds should be calibrated. In cereals, the unevenness of seeds of one seed lot is mainly due to maternal variability. In this regard, the seeds are calibrated to obtain the equalized fractions in size or specific weight [8].

Sieves have fixed cell size, but despite this, in different years the seeds of the same width differed in thousand grain weight (Table 1).

The authors used the original design of the experimental sample of the modified air separator (without sieves). The adjustment of its working body allows obtaining fractions taking into account the thickness of seeds. Therefore, using this type of separator a greater number of fractions can be extracted. In 2017 the seeds that obtained the smallest thickness (Variants AS 1, AS 2) were characterized by high thousand grain weight (more than 40 g).

Only 2 or 3 fractions of seeds can be calibrated using conventional design of aerodynamic separator, and seeds of these fractions not often have differences in thousand grain weight.
Table 1. Dependence of winter wheat thousand grain weight (g) on the calibration method

| Variant | Growing season          |          |          |          |
|---------|-------------------------|----------|----------|----------|
|         | 2014-2015               | 2015-2016| 2017-2018|
| Control | 38.4                    | 36.2     | 43.0     |
| SS 2.2  | 30.2                    | 28.8     | 34.7     |
| SS 2.5  | 45.2                    | 40.0     | 45.8     |
| SS 3.0  | 50.4                    | 47.4     | 55.7     |
| SSieve separator |          |          |          |
| AS 1    | 26.5                    | 24.3     | 43.7     |
| AS 2    | 34.2                    | 31.9     | 46.5     |
| AS 3    | 41.8                    | 38.1     | 53.4     |
| AS 4    | 49.3                    | 43.8     | 59.4     |
| AS Experimental sample of the modified air separator | | | |
| SAD 2   | 40.9                    | 37.3     | 46.0     |
| SAD 3   | 38.7                    | 25.4     | 41.9     |
| AS Aerodynamic separator |          |          |          |

The assessment of the evenness of seeds was carried out using the coefficient of variation characterizing the variability of the weight of the caryopsis of each seed lot. In variants where calibration was performed by size, the evenness increased annually from small seeds to large ones. The highest level of evenness of seeds was observed in variants of large fractions (Variants SS 3.0, AS 4) (Table 2).

Table 2. Dependence of the evenness of seeds on the calibration method

| Variant | Coefficient of variation (%) |          |          |          |
|---------|-----------------------------|----------|----------|----------|
|         | 2014-2015                   | 2015-2016| 2017-2018|
| Control | 21.6                        | 23.3     | 13.1     |
| SS 2.2  | 14.6                        | 22.5     | 15.8     |
| SS 2.5  | 10.1                        | 14.5     | 14.7     |
| SS 3.0  | 7.8                         | 11.2     | 10.8     |
| SSieve separator |          |          |          |
| AS 1    | 13.9                        | 21.2     | 20.2     |
| AS 2    | 12.3                        | 15.6     | 10.3     |
| AS 3    | 11.4                        | 11.4     | 9.8      |
| AS 4    | 8.0                         | 10.2     | 7.5      |
| AS Experimental sample of the modified air separator | | | |
| SAD 2   | 17.0                        | 24.5     | 13.2     |
| SAD 3   | 17.6                        | 36.3     | 16.2     |
| AS Aerodynamic separator |          |          |          |

The seeds of the control variant were characterized by less evenness.

4. Assessment of ecological properties of seeds

The assessment of ecological properties of the variety is usually carried out in two stages. In the beginning, using the method of dispersive analysis the evidence of factors interaction is defined. In our case, these factors were ‘fraction × year’ and ‘fraction × sowing period’. These factors exerted practically certain impact on the productivity of winter wheat plants (Table 3).

In the variant with small seeds (Variant AS 1) and seeds of low specific weight (Variant SAD 3) the influence of the factors ‘year’ and ‘sowing period’ was uncertain (Table 4).
Table 3. Dependence of the productivity of winter wheat plants on seed size, conditions of growing season of the year, and sowing date

| Factor                      | SS    | Degree of Freedom | MS     | F       | p     |
|-----------------------------|-------|-------------------|--------|---------|-------|
| Intercept                   | 17514.4 | 1                | 17514.4 | 8551.1  | 0.00  |
| Year                        | 72.7   | 2                 | 36.4   | 17.8    | 0.00  |
| Fraction                    | 34.2   | 9                 | 3.8    | 1.9     | 0.05  |
| Year × fraction             | 92.1   | 18                | 5.1    | 2.5     | 0.00  |
| Error                       | 3895.7 | 1902              | 2.0    |         |       |

**Conditions of growing season of the year**

| Intercept                   | 22372.9 | 1                | 22372.9 | 11380.3 | 0.00  |
| Fraction                    | 55.4    | 9                 | 6.2     | 3.1     | 0.00  |
| Sowing period               | 102.7   | 2                 | 51.4    | 26.1    | 0.00  |
| Sowing period               | 220.7   | 18                | 12.3    | 6.2     | 0.00  |
| Error                       | 3739.2  | 1902              | 2.0     |         |       |

Table 4. Assessment of influence of the environmental conditions of the year and sowing period on the productivity of winter wheat plants depending on the variant of seed calibration

| Factor                      | SS    | Degree of Freedom | MS     | F       | p     |
|-----------------------------|-------|-------------------|--------|---------|-------|
| Year                        | 39.4  | 2.0               | 19.7   | 8.3     | 0.00  |
| Sowing date                 | 27.3  | 2.0               | 13.7   | 5.8     | 0.00  |
| Sowing period               | 26.9  | 2.0               | 13.4   | 8.4     | 0.00  |
| Sowing date                 | 5.5   | 2.0               | 2.7    | 1.7     | 0.18  |
| Year                        | 6.0   | 2.0               | 3.0    | 1.7     | 0.18  |
| Sowing date                 | 17.9  | 2.0               | 9.0    | 5.2     | 0.01  |
| Sowing period               | 7.6   | 2.0               | 3.8    | 2.0     | 0.14  |
| Sowing date                 | 43.4  | 2.0               | 21.7   | 11.2    | 0.00  |
| Year                        | 4.9   | 2                 | 2.4    | 1.6     | 0.21  |
| Sowing date                 | 7.0   | 2                 | 3.5    | 2.3     | 0.11  |
| Sowing period               | 23.1  | 2                 | 11.6   | 5.5     | 0.00  |
| Sowing date                 | 39.5  | 2                 | 19.7   | 9.4     | 0.00  |
| Year                        | 10.2  | 2                 | 5.1    | 2.6     | 0.08  |
| Sowing date                 | 30.6  | 2                 | 15.3   | 7.8     | 0.00  |
| Sowing period               | 14.8  | 2                 | 7.4    | 4.7     | 0.01  |
| Sowing date                 | 12.5  | 2                 | 6.3    | 4.0     | 0.02  |
| Year                        | 23.6  | 2                 | 11.8   | 7.4     | 0.00  |
| Sowing date                 | 22.6  | 2                 | 11.3   | 7.1     | 0.00  |
| Sowing period               | 7.5   | 2                 | 3.7    | 1.9     | 0.15  |
| Sowing date                 | 0.1   | 2                 | 0.1    | 0.0     | 0.97  |

Factor ‘sowing period’ did not exert practically certain impact on the productivity of plants grown from seeds of small fractions (Variant SS 2.2; Variant AS 1; Variant SAD 3).

Knowing the adaptive properties of the variety specialists can choose the best practical cultivation
technology [9, 10]. For this purposes the breeders use different techniques [11, 12]. In the experiments the authors use several ecological parameters of varieties response to ecological conditions. They are:

(i) an integral indicator of the level of the variety productivity stability [13];
(ii) homeostatic indices (Hom);
(iii) selective value indicator (Sc) [14];
(iii) regression coefficient (Ri) calculated by the main axis method [15] and used for an assessment of the variety responsiveness to vegetation conditions.

In view of the results of homeostatic indices (Hom) calculation, it is clear that the seeds of Fraction AS 4 provide the highest homeostatic properties, because at sufficiently high plant productivity smaller scale variations are observed when cultivation conditions change (Table 5).

Table 5. Productivity of winter wheat plants, homeostatic and response indices depending on seed fractions

| Variant | Date of sowing | Homeostatic indices (Hom) | Regression coefficient (R) |
|---------|---------------|--------------------------|--------------------------|
| Control | 05.09.14      | 12.1                     | 1.00                     |
|         | 16.09.14      |                          |                          |
|         | 26.09.14      |                          |                          |
|         | 04.09.15      |                          |                          |
|         | 15.09.15      |                          |                          |
|         | 25.09.15      |                          |                          |
|         | 05.09.17      |                          |                          |
|         | 15.09.17      |                          |                          |
|         | 26.09.17      |                          |                          |
| SS 2.2  | 3.50          | 3.34                     | 3.62                     |
|         | 2.02          | 3.62                     | 2.61                     |
| SS 2.5  | 3.94          | 2.80                     | 3.48                     |
|         | 2.22          | 3.86                     | 2.36                     |
| SS 3.0  | 5.13          | 3.54                     | 2.83                     |
|         | 3.33          | 2.69                     | 3.00                     |
| AS 1    | 3.30          | 2.89                     | 3.00                     |
|         | 3.20          | 2.87                     | 2.52                     |
| AS 2    | 3.64          | 2.95                     | 3.87                     |
|         | 2.31          | 2.66                     | 4.75                     |
| AS 3    | 3.06          | 4.00                     | 2.62                     |
|         | 3.22          | 2.98                     | 2.73                     |
| AS 4    | 3.66          | 3.23                     | 3.96                     |
|         | 2.88          | 2.67                     | 3.56                     |
| SAD 2   | 3.87          | 2.93                     | 3.13                     |
|         | 2.82          | 2.72                     | 3.73                     |
| SAD 3   | 3.43          | 3.83                     | 3.32                     |
|         | 2.83          | 2.77                     | 3.44                     |

The following patterns were defined within different treatment combinations:

(i) homeostatic indices of the variety decreased when the size of seeds calibrated using sieve separator or aerodynamic separator increased;

(ii) homeostatic indices of the variety increased when the seeds were calibrated using an experimental sample of the modified air separator.

When sowing seeds calibrated by sieve or aerodynamic separator, the responsiveness of plants to the conditions of the growing season increased from small fractions to large ones, and an inverse trend manifested itself at sowing seeds calibrated by an experimental sample of the modified air separator.

5. Conclusions

The following conclusions can be derived on the basis of the results of the research.

Variability trend of the adaptive properties of the crop variety depends on the method of seed calibration, and it should be taken into account at seed preparation for sowing using different winter wheat cultivation technologies:

(i) in intensive cultivation technologies the highest responsiveness of winter wheat plants to the conditions of the growing season is observed when the seeds are calibrated using sieve separator (Variant SS 3.0), aerodynamic separator (Variant SAD 3), and an experimental sample of the modified
and calibrated by thickness using an experimental sample of the modified air separator without sieves should be used, because the seeds of these fractions provide the highest level of crop variety homeostatic indices.

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