Characteristics of Agricultural Lands, the Estimation of Yield of Grain and Leguminous Crops Varieties and Parameters of Their Adaptability in the Tyumen Region

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Abstract. The priority task of the agricultural sector of the Russian Federation is the production of food grain. The article describes the characteristics of agricultural lands for 2004-2018, the area of sowing and yield of the grain and leguminous crops for 2014-2018, as well as the assessment of yield and adaptive potential of the main varieties of the grain and leguminous crops for 2017-2019 in the Tyumen region. On average, in 2004-2018, the total area of agricultural lands amounted to 2352.6 thousand hectares, and the area of the field – 1119.1 thousand hectares. The time dynamics showed an increase of the total area of agricultural lands and a decrease of the area of the field. The area of sowing of the grain and leguminous crops averaged 689.4 thousand hectares in 2014-2018, and the average yield was 2.06 tons/ha. The leading grain crop is spring wheat. The average sowing area of spring wheat was 402.9 thousand hectares with an average yield of 1.95 tons/ha. The variability of grain and leguminous crops yield ranged from small to significant, while the coefficient of yield stability ranged from 1.0 (winter wheat) to 5.3 (winter rye). The largest average yield of spring wheat was observed in the middle-early variety Tyumenskaya 25 (5.21 t/ha) and middle-season variety Aviad (5.00 t/ha), in the spring barley – Abalak (4.69 t/ha), in the oats – Foma (6.07 t/ha) and peas – Thomas (4.37 t/ha). In general, all varieties of grain and leguminous crops were characterized by low stress resistance, and their yield variability ranged from small to significant. The index of ecological plasticity of the majority of varieties was equal to and close to one, which characterizes them as plastic, i.e. the change in their yield fully corresponds to the change in growing conditions. The variety of spring wheat Tyumenskaya 25 was the best in terms of general adaptive ability (GAA = 0.20), the variety of spring barley – Abalak (GAA = 0.15), the variety of oats – Foma (GAA = 0.20) and the variety of peas – Thomas (GAA = 0.18). The variety of the spring barley Abalak (GAA = 0.15; Cv = 6.6%) and the pea variety Thomas (GAA = 0.18; Cv = 5.3%) were the best varieties combining a high level of general adaptive ability with a small yield variability.

1. Introduction

Land in agriculture is the main means of production. Its rational use has a significant impact on the efficiency of the industry and the socio-economic situation in the village [1].

In accordance with the land legislation of the Russian Federation, all lands of the country are divided into seven categories for the main purpose. The main and most valuable category of lands is
the first – agricultural lands, which is intended for the needs of agriculture. Agricultural lands are allocated in this category of lands, in which the field is the most intense species [2].

At present, worldwide, including Russia, there is a decrease of the area of the field against the population growth and at the same time the problem of effective use and degradation of land has intensified. Thus, as of 1.01.2019, the area of the field in the country amounted to 115.8 million hectares and decreased by 5.8 million hectares compared to 2014 (121.5 million hectares in 2014) [3,4].

The priority task of the agricultural sector of the Russian Federation is the production of food grain to ensure the need of the population for high-quality bread. For grain crops growing, Russia has enormous potential – 8.7% of the world's field, 5.5% of black-earth soils [5,6].

According to the data for 2018, the area of sowing of grain and leguminous crops in Russia amounted to 46339 thousand hectares, and the yield – 2.54 tons/ha [4].

An important problem of the grain production is its stabilization, the level of which is largely influenced by adverse natural factors leading to variability of a gross yield. As a result of climate change in our country, such regions as the North Caucasus, the Volga region and Southern Siberia will be the most vulnerable in the future, where 70% of grain crops are sown [7].

New varieties and hybrids are the most real and effective means in increasing the productivity of agroecosystems. According to various sources, the variety accounts for 25-40% of the total yield growth of the most important crops. Thus, in Omsk region as a result of breeding it was possible to achieve 2-fold increase in yield of spring wheat [8,9]. In the Tyumen region in 1929-2015 there were six change of spring wheat varieties, each of which on average provided a yield increase of 0.22 tons/ha [10]. The variety zoning of grain and leguminous crops in the Tyumen region for 2019 includes 43 varieties, of which spring wheat – 16 [11].

The main reserve for grain crop yield growth is the most complete realization of the potential productivity of allowed for use varieties. At the same time, conducted change of varieties do not always and not in all regions lead to an increase in yield, primarily because the potential of new varieties even under optimal growing conditions is realized by only 50-60% due to their insufficient adaptability [12,13].

As the potential productivity of varieties increases, their ecological dependence increases, and the gap between minimum and maximum of productivity increases. Thus, the one-sided orientation towards high potential productivity is not effective enough because it cannot be realized under adverse conditions [12,14].

In this regard, increasing of the ecologic resistance of varieties is the most important task of breeding in ensuring high and stable yields under different growing conditions. Modern varieties should combine high yield and product quality with resistance to adverse environmental factors, i.e. be highly adapted [15-20]. The adaptive variety is an ecologically plastic variety, which adapted not only to the optimum, but also to the minimum and maximum of environmental factors [21].

The purpose of the study is the estimation of the structure of agricultural lands, the yield of cereals and the adaptive potential of their varieties in the Tyumen region.

2. Materials and methods

The material of the study was the data of the Report on the environmental situation in the Tyumen region on the use of agricultural lands for 2004-2018 [22], the data of the Federal service of State Statistics of the Tyumen Region on the production of crop production for 2014-2018 [23], the data of variety zoning of agricultural crops and results of variety testing in the Tyumen region for 2017-2019 [11].

Variability of yield (coefficient of variation) of grain and leguminous crops and yield of their varieties was determined by B.A. Dospehov's method [24], and coefficient of yield stability – by R.N. Ushakov's method [25]. Stress resistance of varieties was determined according to equations A.A. Rosielle, J. Hemblin [26] in the statement of A.A. Goncharenko [11], and index of ecological plasticity and general adaptive ability of varieties – respectively according to the methods of A.A. Gryaznov [27] and A.V. Kilchevsky, L.V. Hotyleva [28].
3. Discussion of results

On average, in 2004-2018, the total area of agricultural lands in the Tyumen region averaged 2352.6 thousand hectares (table 1).

Table 1. Agricultural lands and its use in commercial production of the Tyumen region.

| Years       | Agricultural lands – in all, thousand hectares | Including by species | Of these, used in commodity production |
|-------------|-----------------------------------------------|----------------------|----------------------------------------|
|             |                                               | field | haymaking | pastures |                                               |                                 |
|             |                                               | thou- | тыс. га  | thou- | thou- |
|             |                                               | sand | %        | sand | sand |
|             |                                               | hectares |          | hectares | hectares | %        |
| 2004-2008   | 2352.4                                        | 1132.1 | 48.1     | 257.6 | 11.0 | 274.4 | 11.7 | 1708.1 | 72.6 |
| 2009-2013   | 2318.7                                        | 1111.5 | 47.9     | 236.7 | 10.2 | 257.5 | 11.1 | 1677.3 | 72.3 |
| 2014-2018   | 2386.6                                        | 1113.6 | 46.7     | 255.7 | 10.7 | 268.7 | 11.2 | 1732.6 | 72.6 |
| 2004-2018   | 2352.6                                        | 1119.1 | 47.6     | 249.8 | 10.6 | 266.9 | 11.3 | 1706.0 | 72.5 |

* - taking into account the areas occupied with long-term plantings, personal subsidiary farms, sites of collective and individual gardening and livestock production, kitchen gardens

There was an increase of their area in the last five-year period (2014-2018) by 34.2 and 67.9 thousand hectares respectively compared to 2004-2008 and 2009-2013 due to the land areas specified in footnote Table 1.

The area of field on average for 2004-2018 amounted to 1119.1 thousand hectares or 47.6% of the general area of agricultural lands. Its decrease in the time dynamics of the analyzed period was noted. Thus, on average, in 2014-2018 its area decreased by 18.5 thousand hectares compared to 2004-2008. Such a decrease of the area of field is due to the transfer of part of agricultural lands to other categories, as well as the non-use of areas of low-productive field due to their degradation and reduction of fertility.

The area of haymaking and pastures in share terms respectively on average amounted to 10.6 and 11.3% of the general area of agricultural lands in 2004-2018. In the time dynamics of the analyzed period, when compared with 2004-2008, there was a decrease of the area of these lands and, especially, in 2009-2013 (table 1).

There was a slight increase of their area on average in 2014-2018 compared to 2009-2013 for all types of lands.

The area of agricultural lands used in commercial production for 2014-2018 on average amounted to 1706.0 thousand hectares or 72.5% of the general area of agricultural lands (table 1). In the time dynamics we have not detected changes in the area of agricultural lands used in commodity production.

The area of sowing of grain and leguminous crops on average amounted to 689.4 thousand hectares in 2014-2018 in the Tyumen region (table 2). The leading grain crop is spring wheat – 402.9 thousand hectares or 58.4% of the general area of grain and leguminous crops. On the second and third places in the area of sowing are spring barley and oats, respectively 142.3 and 104.8 thousand hectares (20.6% and 15.2%).
Table 2. The area of sowing and characteristic of productivity of grain and leguminous crops in the Tyumen region, 2014-2018.

| Crop                      | Area of sowing | Yield, t/ha | Variability of yield (coefficient of variation), Cv% | Coefficient of yield stability (Ks) |
|---------------------------|----------------|-------------|-----------------------------------------------------|-------------------------------------|
|                           | thousand hectares | min | max | average |                                                   |                                    |
| The grain and leguminous crops – in all | 689.4 | 100.0 | 1.88 | 2.33 | 2.06 | 8.7 | 4.2 |
| Winter wheat              | 3.7            | 0.5 | 1.58 | 3.17 | 2.37 | 24.5 | 1.0 |
| Winter rye                | 1.8            | 0.3 | 2.08 | 2.47 | 2.29 | 6.6  | 5.3 |
| Spring wheat              | 402.9          | 58.4 | 1.75 | 2.22 | 1.95 | 8.7 | 3.7 |
| Spring barley             | 142.3          | 20.6 | 2.06 | 2.57 | 2.27 | 10.6 | 4.0 |
| Oats                      | 104.8          | 15.2 | 1.84 | 2.43 | 2.12 | 10.8 | 3.1 |
| The leguminous crops      | 29.8           | 4.3 | 1.75 | 2.64 | 2.21 | 15.8 | 2.0 |

The area of sowing of winter crops in the region is insignificant and on average amounted to 3.7 thousand hectares (winter wheat) and 1.8 thousand hectares (winter rye) in 2014-2018. The main reason for the expansion of the area of winter crops is the absence of winter-resistant varieties as the main factor of yield formation in different weather conditions.

The area of leguminous crops in the region is relatively low – 29.8 thousand hectares (4.3%) and requires an increase based on the food and feed value of these crops and the role in the accumulation of easily absorbed nitrogen in the soil. Such an increase in the area of leguminous crops, in particular peas, is possible due to the presence of varieties resistant to fasting (leafless morphotype) and showering (non-shedding morphotype).

The lowest (min) yield of cereals for the period from 2014 to 2018 was observed in winter wheat (1.58 t/ha), spring wheat and legumes (1.75 t/ha, respectively), and the largest yield potential (max) was revealed in winter wheat – 3.17 t/ha (table 2).

The average yield of grain and leguminous crops for 2014-2018 was 2.06 tons/ha. The winter wheat (2.37 t/ha) and spring barley (2.27 t/ha) were the best winter crop in this indicator (table 2). Spring wheat, as the most valuable of the cereals, is inferior in average yield (1.95 t/ha) to other crops, primarily due to insufficient yield potential of allowed for use varieties.

The yield variability is small in grain and leguminous crops – in all (8.7%), winter rye (6.6%) and spring wheat (8.7%), and in other crops it is medium, except for winter wheat, where this indicator has a significant value (24.5%) (table 2).

An additional characteristic of yield variability, which is estimated on the basis of the value of minimum and maximum yields rather than its dispersion, is the coefficient of stability, which estimates the stability of crop yields rather than their individual varieties. In terms of the value of this indicator there are partially different patterns of distribution of crops than in terms of the variability of yield. The winter wheat (Ks = 1.0) is the best in terms of yield stability, and the lowest values of this parameter are founded in winter rye (Ks = 5.3) (table 2).
The main area of sowing of grain and leguminous crops in the Tyumen region is concentrated in the III natural and climatic zone – northern forest steppe. In this regard, we describe the yield and adaptive potential of allowed for use varieties based on the results of their testing at the Ishimsky STP located in this zone. Since the area of sowing of winter crops in the region is insignificant, we have given an estimate of the varieties of only spring cereals and peas.

Most varieties of grain and leguminous crops had high yield potential. Its largest value is found in oats varieties – from 6.85 t/ha (Talisman) to 7.24 t/ha (Otrada), as well as in middle-season varieties of spring wheat – from 5.50 t/ha (Tyumenskaya Jubileynaya) to 6.22 t/ha (Tyumenskaya 25) (table 3).

Table 3. Productivity and adaptability of the main varieties of grain and leguminous crops, 2017-2019 (III zone, northern forest-steppe, Ishimsky STP).

| *Crop, variety | Year of allowed min | Yield, t/ha | Stress resistance | Variability of yield | General adaptive ability (GAA) |
|----------------|---------------------|-------------|-------------------|---------------------|-----------------------------|
|                | for use (Y₁)        | (Y₂)        | (Y₁-Y₂)           | (coefficient of variation), % |                           |
| Spring wheat, middle-early varieties |
| Tyumenskaya 25  | 2012 4.36 6.22 5.21 | -1.86       | 18.0              | 1.04                | 0.20                        |
| Ekatherina      | 2015 4.23 5.70 5.05 | -1.47       | 14.8              | 1.01                | 0.04                        |
| Tyumenskaya Jubileynaya | 2018 4.35 5.50 4.77 | -1.15       | 13.2              | 0.96                | -0.24                       |
| Spring wheat, middle-season varieties |
| Aviada          | 2004 4.07 5.87 5.00 | -1.80       | 18.0              | 1.02                | 0.13                        |
| Omskaya 36      | 2008 4.30 5.26 4.67 | -0.96       | 10.9              | 0.96                | -0.20                       |
| Tyumenskaya 29  | 2013 4.00 5.53 4.95 | -1.53       | 16.8              | 1.01                | 0.08                        |
| Spring barley   |
| Acha            | 2001 4.33 4.73 4.56 | -0.40       | 4.6               | 1.01                | 0.02                        |
| Chelyabinovsky99 | 2004 3.94 4.91 4.38 | -0.97       | 11.2              | 0.96                | -0.16                       |
| Abalak          | 2015 4.44 5.04 4.69 | -0.60       | 6.6               | 1.03                | 0.15                        |
| Oats            |
| Talisman        | 2002 5.23 6.85 5.80 | -0.62       | 15.7              | 0.99                | -0.07                       |
| Otrada          | 2013 4.77 7.24 5.75 | -2.47       | 22.8              | 0.97                | -0.12                       |
| Foma            | 2015 5.42 7.16 6.07 | -1.74       | 15.6              | 1.04                | 0.20                        |
| Pea             |
| Kumir           | 2015 3.36 4.41 3.96 | -1.05       | 13.6              | 0.94                | -0.23                       |
| Salamanka       | 2016 3.64 4.67 4.25 | -1.03       | 12.7              | 1.01                | 0.06                        |
| Thomas          | 2017 4.15 4.61 4.37 | -0.46       | 5.3               | 1.05                | 0.18                        |

* -spring grain crops – background fallow
- pea – background spring wheat

The variety Tyumenskaya 25 (5.21 t/ha) was characterized the highest average yield in the group of middle-early varieties of spring wheat, and in the group of middle-season varieties – the variety Aviada (5.00 t/ha).

The variety of spring barley Abalak (4.69 t/ha) and the oats variety Thomas (6.07 t/ha) have the highest average yield.

The variety of peas Thomas (4.37 t/ha) was the best on average yield (table 3).

In conditions of modern plant cultivation technologies and the growth of potential productivity of varieties, the value and quality of the yield depends on unregulated environmental factors in a large extent [19]. In this regard, the creation and introduction of ecological sustainable varieties providing high and stable yields into production is relevant.
According to our research in general, all varieties of grain and leguminous crops were characterized by low stress resistance. The varieties of spring wheat Tyumenskaya Jubileynaya (-1.15, middle-early) and Omskaya 36 (-0.96, middle-season), variety of spring barley Acha (-0.40), the variety of oats Talisman (-1.62) and the variety of peas Thomas (-0.46) were the best varieties with relatively high stress resistance.

Yield variability supplement to the characteristics of stress resistance of varieties in their integrated estimation of ecological stability. According to our studies, depending on the variety, the yield variability ranged from small to significant (table 3). The lowest yield variability was revealed in the same varieties, which were also characterized by the highest stress resistance. There is an inverse relationship between stress resistance and crop yield variability.

The index of ecological plasticity of varieties allows to giving them an estimate of the value of responsiveness to change of growing conditions. In the majority of varieties the index of ecological plasticity is equal to and close to one, which characterizes them as plastic. The change of their yield fully corresponds to the change of growing conditions. The index of ecological plasticity (IEP) of spring wheat varieties changed from 0.96 (Tyumenskaya Jubileynaya, Omskaya 36) to 1.04 (Tyumenskaya 25), at spring barley – from 0.96 (Chelyabinsky 99) to 1.03 (Abalak), at oats – from 0.97 (Otrada) to 1.04 (Foma), at peas – from 0.94 (Kumir) to 1.05 (Thomas) (table 3). The allowed for use varieties in the most recent years were characterized by a higher index of ecological plasticity than the previous ones. This indicates an increase of their intensity in the time dynamics of allowed for use, which is consistent with the data of other authors [11,12, 29].

The general adaptive ability (GAA) of varieties characterizes their ability to produce high yields under different environmental conditions [29]. The GAA of most of the varieties studied by us is low and varies considerably depending on the variety (Table 3).

The highest values of this indicator were found in the spring wheat variety Tyumenskaya 25 (GAA = 0.20), the spring barley variety Abalak (GAA = 0.15), the oats variety Foma (GAA = 0.20) and the peas variety Thomas (GAA = 0.18). The same varieties had the highest average yield. However, it should be noted that only varieties which combine high general adaptive ability with low yield variability are particularly valuable. Based on this provision, the spring barley variety Abalak (GAA = 0.15; C_v = 6.6%) and the pea variety Thomas (GAA = 0.18; C_v = 5.3%) meet this criterion.

4. Conclusion
In the time dynamics of the analyzed five-year periods, an increase in the area of agricultural lands has been revealed and a decrease in the area of the field. The spring wheat is the leading grain crop in the area of sowing. The largest average yield in 2014-2018 in the group of winter crops was observed in winter wheat, and in the spring crop – in spring barley. The yield variability of most grain and leguminous crops was small and medium. The highest average yield was observed in oat varieties. All varieties of grain and leguminous crops had low stress resistance, and the variability of the most of them was medium. Based on the value of the index of ecological plasticity, most of the varieties are plastic: the change in their yield fully corresponds to the change in growing conditions. Most varieties of grain and leguminous crops had low general adaptive ability.

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