Seed productivity and adaptability potential of varieties and promising lines of sainfoin in the south of the Rostov region

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Abstract. Esparcet is not inferior to alfalfa in terms of fodder mass productivity, its nutritional value, content of protein and other nutrients. The main tasks in creating varieties of sainfoin are the selection of new, with high productivity of green mass and seeds, ecologically adapted, with a sufficiently high plasticity to a wide variation in the environmental conditions of its cultivation zones, varieties. The purpose of the research is to assess the plasticity, stability, stress resistance, genetic flexibility and homeostaticity of varieties and promising lines of sainfoin on the basis of “seed yield”. The studies were carried out in 2017-2021. Plot area 20 m², fourfold repetition, seeding rate 500 pcs. germinating seeds per 1 m². Seed harvesting was carried out by direct combining. Over the years of research, the seed yield was higher for the Atamansky 20 variety (0.86 t/ha) and the promising lines Sin 3/2004 (0.88 t/ha), Sin 5/2010 (0.91 t/ha) and Sin 3/2010 (0.94 t/ha). It was established that varieties Veles (bi = 0.15), Atamansky (bi = 0.29) and Zernogradsky 2 (bi = 0.32) react poorly to changing conditions. The values of the stability coefficient of the studied varieties and lines varied from 0.0009 to 0.0076. The sainfoin varieties Sudar (σ²d = 0.0009), Atamansky (σ²d = 0.0010), Veles (σ²d = 0.0015) have the highest stability. The varieties of sainfoin Atamansky, Sudar, Atamansky 20 and Veles were distinguished by wide homeostaticity. They have high plasticity, stability and stress resistance.

1 Introduction

In many regions of Russia, sainfoin is an important fodder perennial legume. It is not inferior to alfalfa in terms of fodder mass productivity, its nutritional value, content of protein and other nutrients. Esparcet is optimally included in the short crop rotations that have become widespread and, as a precursor for winter crops, is not inferior to peas, chickpeas and soybeans, and is also one of the best green manure crops in the south of the country [1–6].
plasticity to a wide variation in the environmental conditions of its cultivation zones, varieties [7–9].

A significant obstacle to the expansion of the area of cultivation of perennial grasses, including sainfoin, is the low and unstable seed yield over the years. Increasing the seed productivity of new varieties of forage grasses is an important breeding work [10–12].

One of the modern directions that increase the seed productivity of forage grasses can be adaptive breeding, which is understood as the ability of a genotype to maintain its characteristic phenotypic manifestation of a trait under different environmental conditions and to identify its response under stressful and favorable conditions [13–15].

Studying the response of the initial material of varieties and new lines of sainfoin to abiotic cultivation conditions in order to identify the most promising ones for use in production and the use of this material with useful adaptive traits when creating new varieties is of great importance.

The aim of the research was to evaluate the plasticity, stability, stress resistance, genetic flexibility and homeostaticity of varieties and promising lines of sainfoin on the basis of "seed yield".

2 Materials and methods

The work was carried out in 2017–2021 on the lands of the Federal State Budgetary Scientific Institution, Agrarian Research Center “Donskoy” (ARC “Donskoy”), located in the southern zone of the Rostov region. As part of the competitive variety testing, six varieties of sainfoin of the ARC “Donskoy” breeding, approved for use in different regions of the Russian Federation, and three promising lines served as material for research.

Field experiments, phenological observations and biometric records were carried out according to the "Methodological guidelines for the selection and seed production of perennial grasses" (1985), "Methodology of the State variety testing of agricultural crops" (2019).

The soil of the site is an ordinary heavy loamy calcareous chernozem. In the plow horizon, the content of humus in the soil was 3.2%, pH – 7.2, mobile phosphorus P 05 – 18 mg/kg, exchangeable potassium K 0 – 320 mg/kg.

Plot area 20 m², fourfold repetition, seeding rate 500 pcs. germinating seeds per 1 m². Standard sainfoin variety Zernogradsky 2. Seeds were harvested by direct combining.

When browning 90–95% of the beans, the sowing was treated with Tongar desiccant at a dose of 3 l/ha and a solution flow rate of 250–300 l/ha. 3–5 days after treatment, the seeds were harvested by the day with a Wintersteiger combine.

The assessment of adaptability parameters was carried out according to the S.A. Eberchart, W.A. Russel (1966) as presented by V.A. Zykina et al. (2011), after A.A. Goncharenko (2005) calculated stress resistance and genetic flexibility, homeostaticity was calculated according to the method of Khangildin (1981).

The research results were processed using Excel for Windows 7.

Over the years of research, a strong variability in meteorological conditions has been observed. Thus, the largest amount of precipitation fell in autumn 2017 and winter 2018 (307.4 mm), which was 110.9% of their long-term average number (277.2 mm), and the smallest for the same period 145.7 mm or 52.6% of the norm–in 2021.

During the spring and summer vegetation periods of 2018, 65.5 mm and 80.7 mm of precipitation, or 50% and 46.3%, respectively, of the average long-term norm of these periods–131.0 mm and 174.2 mm. The largest amount of precipitation–209.6 mm or 60% above the long-term average fell in the spring of 2021. This summer, their amount was 179.6 mm, only 5.4 mm above the long-term average for this period.
The vegetation conditions of this year were the most intense in terms of temperature. In the spring period, the average daily air temperatures were 11.6 °C or 1.9 °C higher than the long-term average (9.7 °C), the temperatures of the summer months (26.1 °C) exceeded the average long-term norm of this period (21.8 °C) by 4.3 °C. In other years, in the spring, the average daily temperatures exceeded the long-term average by 0.2–1.6 °C, and in the summer–by 0.2–3.0 °C, with a lack of moisture in different months of these periods.

3 Results and discussion

The variability of seed yield of varieties and promising lines of sainfoin in the experiment, according to the results of the analysis of variance, is 51.9% determined by the variety (genotype). The influence of environmental conditions on its variability is 5.1%, and 33.5% of the variability is due to the interaction of the variety and the environment. The interaction between factors is also significant and significant at the 5% level (Table 1).

Table 1. The results of a two-way analysis of variance of varieties and promising lines of sainfoin on the basis of “seed yield” (2017–2021).

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squares, SS</th>
<th>Number of degrees of freedom, df</th>
<th>Mean squares (variance), MS</th>
<th>Ffact.</th>
<th>Ftheor.</th>
<th>Influence of factors, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>8654,42</td>
<td></td>
<td>53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor А</td>
<td>4489,42</td>
<td>8</td>
<td>561,18</td>
<td>36,46</td>
<td>2,10</td>
<td>51,9</td>
</tr>
<tr>
<td>Factor В</td>
<td>439,86</td>
<td>5</td>
<td>87,97</td>
<td>5,71</td>
<td>2,40</td>
<td>5,1</td>
</tr>
<tr>
<td>Factor АВ</td>
<td>2903,46</td>
<td>40</td>
<td>72,59</td>
<td>4,72</td>
<td>1,60</td>
<td>33,5</td>
</tr>
<tr>
<td>Random</td>
<td>815,74</td>
<td>53</td>
<td>15,93</td>
<td></td>
<td></td>
<td>9,5</td>
</tr>
</tbody>
</table>

Note: Factor А – genotype, factor В – environment, factor АВ – interaction genotype x environment.

The average seed yield of sainfoin varieties and lines in the years of the experiments was 0.83 t/ha (Table 2).

Table 2. The influence of growing conditions on the yield of seeds of varieties and promising lines of sainfoin, their plasticity and stability (2017–2021).

<table>
<thead>
<tr>
<th>Variety / line</th>
<th>Sowing year</th>
<th>Average, t/ha</th>
<th>CV, %</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2017</td>
<td>2018</td>
<td>2019</td>
<td>2020</td>
</tr>
<tr>
<td>Zernogradsky</td>
<td>0.68</td>
<td>0.75</td>
<td>0.79</td>
<td>0.68</td>
</tr>
<tr>
<td>Atamansky</td>
<td>0.73</td>
<td>0.77</td>
<td>0.79</td>
<td>0.75</td>
</tr>
<tr>
<td>Veles</td>
<td>0.74</td>
<td>0.79</td>
<td>0.82</td>
<td>0.76</td>
</tr>
<tr>
<td>Sudar</td>
<td>0.74</td>
<td>0.82</td>
<td>0.78</td>
<td>0.81</td>
</tr>
<tr>
<td>Shuravi</td>
<td>0.78</td>
<td>0.84</td>
<td>0.91</td>
<td>0.80</td>
</tr>
</tbody>
</table>
It was higher than that of the standard Zernogradsky 2, varieties Atamansky, Veles and Sudar, but was inferior to the average yield of the new variety Atamansky 20 (0.86 t/ha), included in the State Register in 2023, and promising lines Sin 5/2010 – 0.91 t/ha, Sin 3/2010 – 0.94 t/ha and Sin 3/2004 – 0.88 t/ha. According to the accounting years, the seed yield was inferior to the average yield for all years in 2018 (0.81 t/ha) and 2020 (0.81 t/ha) and was equal to the crop yield in 2018 and 2019 (0.83 t/ha). In these years, the indices of environmental conditions (Ij) were negative, which indicates less favorable conditions for obtaining a seed crop than in other years, when the indices of environmental conditions were positive, and the average yield in these years was higher – 0.84 – 0.87 t/ha.

The new variety Atamansky 20 and the lines Sin 5/2010, Sin 3/2010 and Sin 3/2004 formed a significantly higher seed yield over the years than the varieties Zernogradsky 2, Atamansky and Veles. The highest yield of the lines (1.01 – 1.09 t/ha) was when taking into account the sowing in 2020 in 2018.

The seed yield variation coefficient was insignificant; the lowest (3.7%) was for the Atamansky variety, the highest (10.8%) was for the Sin 5/2010 line, which indicates a low variability in the seed yield of the studied sainfoin varieties and lines.

The linear regression coefficient (bi), according to the authors of the methodology (Zykin, 2011), “serves as a measure of the response of genotypes to changes in environmental conditions” and represents an assessment of the plasticity of the studied objects. In our case, the coefficient bi shows that the studied varieties and lines are genetically different in terms of plasticity.

Promising lines Sin 5/2010, Sin 3/2010 and Sin 3/2004 are distinguished by a high linear regression coefficient of 2.67, 2.31 and 2.03, respectively; of these lines over the years of study was significantly higher (0.88 – 0.94 t/ha) than in varieties.

The coefficient of linear regression of the variety Sudar (bi = 0.99) is close to unity and this indicates the plasticity of the variety, and the regression coefficient shows that the change in its yield almost completely corresponds to the change in growing conditions.

According to the degree of reaction of the trait “seed yield” to changes in environmental conditions, the studied varieties ranged, taking into account the regression coefficient, from the Veles variety (bi = 0.15), which reacts poorly to changes in environmental conditions, to the Shuravi variety (bi = 0.66), having a greater reaction from sainfoin varieties.

Varieties Atamansky (bi = 0.29), Zernogradsky 2 (bi = 0.32), and Atamansky 20 (bi = 0.42) occupied an intermediate position. The value of the linear regression coefficient of the studied sainfoin varieties, according to Zykin’s method, indicates that they are best used when grown for seeds on an extensive background, where they will give the maximum yield at the minimum necessary cost. They can also become sources for the creation of new varieties with a weak response to changes in seed yield under changing environmental conditions.

The most stable varieties were Sudar ($\sigma^2 = 0.0009$), Atamansky ($\sigma^2 = 0.0010$), Veles ($\sigma^2 = 0.0015$). The stability of the lines Sin 3/2010 ($\sigma^2 = 0.0042$), Sin 3/2004 ($\sigma^2 = 0.0068$) and Sin 5/2010 ($\sigma^2 = 0.0076$) was significantly lower than that of the varieties.

An important feature that must be taken into account when creating new varieties and their subsequent use is stress resistance. Stress resistance reflects the level of resistance of a variety (genotype) to stressful, contrasting conditions that manifest themselves in different periods of its life. According to the ability to form a seed yield under different conditions and to endure stress factors, the studied varieties and lines of sainfoin differed significantly (Table 3).

### Table 3. Parameters of ecological sustainability of varieties and promising lines of sainfoin (2017-2021)

<table>
<thead>
<tr>
<th>Variety / line</th>
<th>Productivity, t/ha</th>
<th>Stress resistance, (min-max)</th>
<th>Genetic flexibility, $\frac{min+max}{2}$</th>
<th>NOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zernogradsky</td>
<td>0.68</td>
<td>0.79</td>
<td>0.11</td>
<td>0.74</td>
</tr>
<tr>
<td>Atamansky</td>
<td>0.73</td>
<td>0.81</td>
<td>0.08</td>
<td>0.77</td>
</tr>
<tr>
<td>Veles</td>
<td>0.74</td>
<td>0.83</td>
<td>0.09</td>
<td>0.79</td>
</tr>
<tr>
<td>Sudar</td>
<td>0.74</td>
<td>0.84</td>
<td>0.10</td>
<td>0.79</td>
</tr>
<tr>
<td>Shuravi</td>
<td>0.77</td>
<td>0.91</td>
<td>0.14</td>
<td>0.84</td>
</tr>
<tr>
<td>Atamansky 20</td>
<td>0.81</td>
<td>0.92</td>
<td>0.11</td>
<td>0.86</td>
</tr>
<tr>
<td>Sin 5/2010</td>
<td>0.79</td>
<td>1.08</td>
<td>0.29</td>
<td>0.94</td>
</tr>
<tr>
<td>Sin 3/2010</td>
<td>0.88</td>
<td>1.09</td>
<td>0.21</td>
<td>0.99</td>
</tr>
<tr>
<td>Sin 3/2004</td>
<td>0.75</td>
<td>1.01</td>
<td>0.26</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Calculations and analysis of the seed yield of the studied varieties and lines of sainfoin show that the varieties Atamansky, Veles, Sudar, Zernogradsky 2 and Shuravi have a higher stress resistance. They have the smallest difference between the minimum and maximum yields, respectively 0.08 t/ha, 0.09 t/ha, 0.10 t/ha and 0.14 t/ha. In the lines Sin 5/2010, Sin 3/2010, Sin 3/2004, due to the large range of variation between the minimum and maximum yields, stress resistance is lower.

The average yield of sainfoin varieties and lines under contrasting conditions gives an idea of their genetic flexibility. In the studies, promising lines Sin 5/2010 (0.94 t/ha), Sin 3/2010 (0.99 t/ha), Sin 3/2004 (0.88 t/ha) stood out for their high genetic flexibility in terms of average seed yield, they had the maximum match between their genotype and environmental factors. Their high level of average yield was formed due to the high yield of seeds under favorable conditions, but the large variability between yields under unfavorable and favorable conditions indicates a significant response of their genotypes to changes in limiting factors, which leads to their low stress tolerance.

The manifestation of homeostaticity is associated with signs of ecological adaptability, since this property lies in the greater or lesser resistance of varieties against seasonal changes in environmental conditions. The identification of homeostaticity is important for crops cultivated in regions with a frequent manifestation of a lack of moisture and high air temperatures.

Identification of the homeostaticity of sainfoin varieties and lines on the basis of "seed yield" showed that the varieties Atamansky (NOM = 20.66), Sudar (NOM = 18.27), Atamansky 20 (NOM = 18.26), Veles (NOM = 18.12). The new lines of sainfoin Sin 3/2010, Sin 3/2004 and Sin 5/2010 have much lower homeostasis – 11.38, 8.94 and 8.45, respectively.
Varieties Atamansky, Sudar, Atamansky 20 and Veles have wide homeostaticity because they have favorable other signs of adaptability responsible for the yield. These are stress resistance, coefficients of plasticity and stability. The studied lines of sainfoin have a potentially higher seed yield, the coefficients of plasticity, stability and stress resistance in them are less favorable under test conditions, but genetic flexibility is higher and, as a result, they form a higher average yield than sainfoin varieties, it is an important indicator of their general adaptability.

4 Conclusions

The studied varieties and lines of sainfoin in terms of seed yield are characterized by different responsiveness to changing growing conditions and indicators of ecological adaptability responsible for it. Atamansky 20 (0.86 t/ha) and promising lines Sin 3/2004 (0.88 t/ha), Sin 5/2010 (0.91 t/ha) and Sin 3/2010 (0.94 t/ha). In the sowing of 2018, the most favorable environmental index (Ij = 0.033) was noted in 2020, when, on average, a higher seed yield (0.87 t/ha) was formed.

The linear regression coefficient (bi), which assesses the plasticity of the response of varieties (genotypes) to changes in environmental conditions, indicates that varieties Veles (bi = 0.15), Atamansky (bi = 0.29) and Zernogradsky 2 (bi = 0.32), and they are best grown on extensive backgrounds and used to create new varieties suitable for cultivation on such backgrounds. The new lines were characterized by a high linear regression coefficient (2.67 - 2.31 - 2.03, they are more responsive to improved growing conditions. The values of the stability coefficient (σd^2) of the studied varieties and lines varied from 0.0009 to 0.0076. The sainfoin varieties Sudar (σd^2 = 0.0009), Atamansky (σd^2 = 0.0010), Veles (σd^2 = 0.0015) have the highest stability. The stability of sainfoin lines turned out to be significantly lower.

The varieties of sainfoin Atamansky, Sudar, Atamansky 20 and Veles were distinguished by wide homeostaticity. they have high plasticity, stability and stress resistance. Possessing a potentially higher seed yield than sainfoin varieties, the new sainfoin lines were distinguished by high genetic flexibility.

References


