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Agroecological assessment of perennial ryegrass varieties in the conditions of the Udmurt Republic

Sergey Kokonov
Plant Science Department
Izhevsk State Agriculture Academy
Izhevsk, Russia
ORCID: 0000-0001-7201-3909

Ivan Temkin
Plant Science Department
Izhevsk State Agriculture Academy
Izhevsk, Russia
v.tyomkin@mail.ru

Tatyana Babaytseva
Plant Science Department
Izhevsk State Agriculture Academy
Izhevsk, Russia
taan62@mail.ru

Elmira Vafina
Plant Science Department
Izhevsk State Agriculture Academy
Izhevsk, Russia
vaf-ef@mail.ru

***Abstract*—In cultivating field crops, the variability of quantitative characteristics is undoubtedly caused by growing conditions and "genotype × environment" interaction. Combined approach to the consideration of this issue showed that the growth of potential productivity of agricultural crops due to selection and cultivation technology adversely affects the resistance of new varieties and hybrids to the influence of abiotic and biotic stresses. This article describes the problem of adapting perennial ryegrass varieties to the conditions of the Udmurt Republic which is one of the reserves of highquality fodder. These studies were performed on sodstrongly podzolic heavyloam soil. The plowing layer of experimental plots had from low (2.1%) to medium (2.6%) humus content, medium (100-101 mg/kg) mobile phosphorus content, from medium (101 mg/kg) to elevated (170 mg/kg) level of mobile potassium. Exchangeable acidity was from medium-acid (pHKCl = 5.0) to close to neutral (pHKCl = 5.6). Results of this research showed that over four years the highest dry matter yield of 3.5 t/ha was formed on average by Malysh variety. The varieties Malysh and Agat – both of Russian selection – were characterized by high winter hardiness (88.0-89.3%), a slight variability in characteristics was noted for these varieties (variation coefficient 6.9-7.3%) what speaks for their stability. The combination of ecological flexibility (bi = 1.13) and phenotypic stability (S2d = 0.10) of Malysh variety reveals its high adaptive properties.**

Keywords*— *perennial ryegrass, ecological flexibility, winter hardiness, productivity.

I. Introduction

The efficiency of agriculture with developed dairy cattle breeding determines the selection of universal field crops used for the harvesting of high-quality fodder [7]. At the same time, main crops for agricultural production should be perennial grasses as a source of cheap fodder. When climate changes the need for new fodder crops becomes important. One of the universal plants used for many purposes is perennial ryegrass. Being one of bluegrass herbs, it is characterized by a relatively high nutritional value. In the fodder production process, it has an advantage of short growing season (65-70 days) and fast aftergrowing after cutting or grazing. Perennial ryegrass is a shade-tolerant crop, so it may be planted under any cover crop and cultivated in shaded areas. The excellent palatability of fodder mass by all animal species determines its multipurpose use both as a pasture crop and for harvesting hay, haylage and silage with high nutritional value. Good leaf coverage of this culture causes a high nutritional value of this fodder. 1 kg of dry matter contains up to 0.82 fodder units, crude protein concentration is 12-18% and is characterized by the presence of all the necessary amino acids. The formation of early-term agrocenoses, including perennial ryegrass, is widely used for intensive grazing of farm animals in Western European countries. This becomes an important line of research in modern Russian fodder production due to the development of new domestic varieties of this crop; this fact is reflected in our work and determines its relevance. Practical significance lies in the fact that the use of perennial ryegrass allows production to receive at least 75 GJ/ha of exchangeable energy.

II. Literature review

The role of external factors in the management of plant potential realization is undeniable. The yield of any variety or hybrid is a result of the complex of important ecological and genetic systems what leads to formation of complex quantitative characteristics. A.A. Zhuchenko [1] proved that the main condition for obtaining the best yield per land unit is the optimization of "plant-environment" system. Thus, he assigned a great role to the agro-ecological regionalization of the territory which allows the better potential realization for varieties and crops. N.I. Vavilov [5] noted: "The harvest is a derivative of the environment and the genotype; it is largely determined by the conditions of the culture and the area." A number of researchers [4, 8, 9] associate variety adaptability with its genetic ability to provide stable and high yield in different environmental conditions. Results of scientific research and world practice convincingly prove that in the total share of agricultural crops productivity increase, a variety or hybrid accounts for about 25-50%. Scientists have proven that the application of new varieties or hybrids contributes to yield increase by about 1%. In this regard, agricultural production places high demands on varieties: precisely, one should pay attention not only to the yield level, but also to stability and resistance. Varieties and hybrids should be tolerant to biotic and abiotic factors of growing conditions and highly technological – that is, an adaptive variety is not only ecologically flexible but is also adapted to optimal conditions and to the appearance of minimum and maximum values of external parameters [10].

Currently, a comparative study of perennial ryegrass varieties has been launched in the Udmurt Republic. In this connection, the issue of studying the ecological flexibility parameters of varieties of a given culture is of great scientific and practical importance.

The goal of this research was to study the culture growth and development in the conditions of the Udmurt

Republic, to analyze the ecological flexibility of ryegrass varieties of domestic and foreign selection, and to identify the most adapted ones to the conditions of this region.

III. Research Methodology

Research methodology was generally accepted one [2]. Investigations were carried out in the northern agroclimatic region of the Udmurt Republic in the Balezinsky State Sorting Plot on sod-strongly podzolic heavy-loam soil. The plowing layer of experimental plots had from low to medium humus content (2.1%-2.6%), medium mobile phosphorus content (100-101 mg/kg), from medium to elevated (101-170 mg/kg) level of mobile potassium., and from medium-acid to close to neutral pH_{KCl} (5.0-5.6). The soil for the experiments met the requirements for the culture.

Experiment scheme included perennial ryegrass varieties of Russian selection: Malysh (originator Ural Agricultural Research Institute – branch of Federal State Budgetary Scientific Institution "Ural Federal Agrarian Research Center" of the Ural Branch of the Russian Academy of Sciences), Agat (originator Federal Research Center "Williams Fodder Research Institute"), and varieties of foreign selection: Bargizmo, Barimero, Barcampo, Bartasia, Barfamos, Boost (Barenbrug Holland, Oregro Seeds INC USA).

In ecological variety test, calculations for perennial ryegrass wintering were carried out in spring at the beginning of aftergrowing phase using the method of counting living and dead plants [11]. Adaptive properties of perennial ryegrass varieties with different origin were calculated according to the method proposed by S.A. Eberhart, W.A. Russel, and set forth by Yu.S. Larionov [12].

IV. Research results

Results of this research showed that studied perennial ryegrass varieties and small difference in the length of growing season, from spring aftergrowing to harvest ripeness, which on average among all varieties lasted for 51-59 days. Experimental data demonstrated that the vegetative period length of perennial ryegrass varieties mainly depended on vegetation conditions rather than on the characteristics of varieties. The shortest growing season (46 days) in varieties was noted in a very dry 2014 when the average daily air temperature during daytime reached + 29... + 33 ° C. Under the conditions of 2017 with excessive precipitation, the growing period of perennial ryegrass increased to 62 days. Vegetation conditions during analyzed years had a significant impact on the winter hardiness of perennial ryegrass varieties. The most favorable conditions for wintering were in the winter-spring period 2015-2016 and 2016-2017. Winter hardiness of varieties on average, by experience, was 91 and 92%, respectively (table 1), and the difference in this parameter between varieties was 1-5% and was characterized by slight variation (V = 1.6-2.8%). Relatively unfavorable wintering conditions were in 2013-2014, as evidenced by low wintering – on average, by experience, 70%, differences between varieties – 17-38%, variation coefficient was significant – 26.6%.

On average, during 4 years of research, Malysh and Agat varieties were characterized by high winter hardiness (88.0-89.3%). For these varieties, an insignificant characteristic variation coefficient (6.9-7.3%) was observed which indicates their stability. Boost variety was characterized by a significant parameter variability (V = 24.6%).

TABLE I. Winter hardiness of perennial ryegrass varieties, %

Variety	2014	2015	2016	2017	Average	Variation coefficient (V), %
Malysh (st.)	90	80	92	95	89.3	7.3
Agat	-	80	92	92	88.0	6.9
Bargizmo	66	78	91	90	81,3	14.5
Barimero	70	82	90	90	83.0	11.4
Barcampo	-	71	90	91	84.0	18.8
Bartasia	77	78	91	91	84.3	11.1
Barfamos	67	75	90	92	81.0	14.8
Boost	52	71	92	-	71.7	24.6
Variation coefficient (V), %	26.6	8.3	1.6	2.8	-	-

The yield of perennial ryegrass varieties during the years of research varied greatly, variation coefficient for this parameter for the whole period according is, by experience, 44.7-66.7% (Table 2). During four years of research, a relatively high yield of 1.31–4.72 t/ha was reached from Malysh variety. Its exceeding the yield of varieties of foreign selection was 0.25-3.82 t/ha, or 5-81%, with the exception of varieties Barfamos in 2014, Boost in 2016 and Barcampo in 2017. Agat variety in 2015 and 2017 in terms of dry matter yield exceeded the yield level of Malysh standard variety by 0.82-1.54 t/ha, i.e. by 18-85%. However, due to its on average unstable productivity over the study period, its yield was 33% lower than the dry matter yield of the standard (3.5 t/ha), i.e. 2.36 t/ha.

TABLE II. Yield of dry matter of perennial ryegrass varieties, t/ha

Variety	2014	2015	2016	2017	Average	Variation coefficient (V), %
Malysh (st.)	3.41	4.57	4.72	1.31	3.50	45.0
Agat	–	5.39	1.21	2.85	2.36	48.1
Bargizmo	2.20	4.32	3.96	0.78	2.82	58.4
Barimero	3.02	3.53	3.57	0.64	2.69	51.7
Barcampo	–	3.89	0.90	1.60	1.60	66.7
Bartasia	2.93	2.78	3.83	1.01	2.64	44.7
Barfamos	3.42	3.00	3.79	0.54	2.69	54.6
Boost	2.81	3.25	5.89	–	2.99	62.4
Variation coefficient (V), %	33.7	35.1	73.4	88.9	-	-

Unfavorable conditions of spring-summer growing season 2016 and 2017 resulted in a strong variability of the yield of perennial ryegrass varieties (V = 73.4-88.9%). During relatively favorable for perennial ryegrass 2014 and 2015, yield variation was 33.7-35.1%. Such yield variation

shows significant differences in the adaptability of varieties to local conditions.

To identify the closeness and nature of this connection, a correlation analysis was carried out. It was established that dry matter yield of perennial ryegrass varieties had an average positive correlation with winter hardiness (r = 0.40) and leaf coverage (r = 0.45).

It is believed that high selection efficiency is expected to be performed on the basis of signs which variability is largely determined by genotype. Similar can be noted for the selection of varieties for cultivation in certain agro-ecological conditions. In our studies, the largest genotype contribution of 34.2% was noted only for of winter hardiness (Fig. 1). Consequently, when choosing varieties of perennial ryegrass for cultivation in the Udmurt Republic, it is necessary, first of all, to take into account their winter hardiness. Aftergrowing of crop plants after wintering and cutting, and, consequently, the yield are highly dependent on many environmental factors. This is evidenced by the high contribution of "environment" factor to the variability of crop yields and plant height (47.5 and 48.4%); the share of genotype influence was only 10.0-20.1%. Therefore, it is hard to select varieties on the basis of these characteristics.

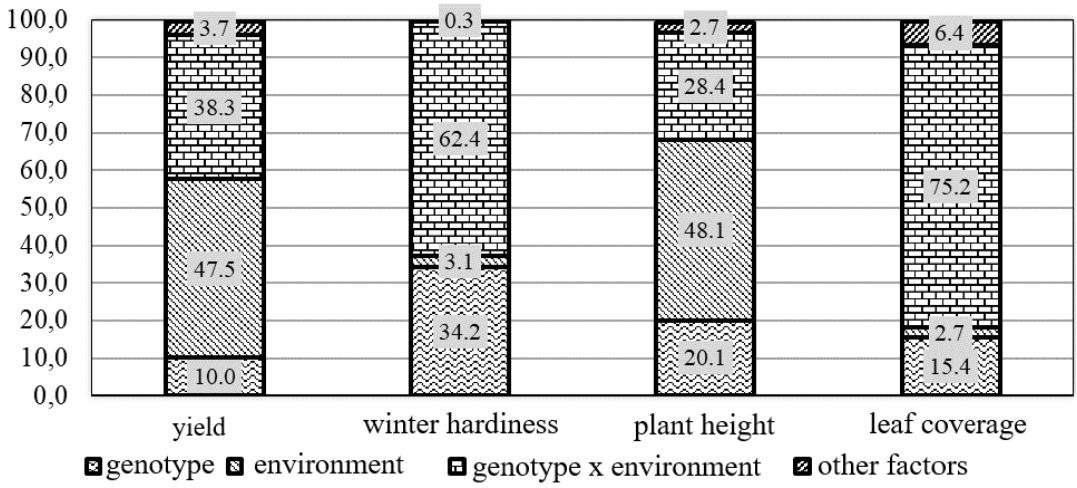

Fig. 1. The contribution of studied factors to the variability of the main quantitative characteristics of perennial ryegrass (2014-2017), %

The share of "genotype × environment" interaction was higher for winter-hardiness formation (62.4%) and leaf coverage (75.2%) what proves a significant variation of characteristics depending on variety and current conditions.

Thus, for the selection of adaptive varieties, it is necessary to establish their stress resistance, flexibility, stability.

Stress resistance is determined by the difference between the minimum and maximum parameter value. The smaller this gap is, the higher is variety's resistance to stressful growth conditions. Malysh and Agat varieties, both of the Russian selection, as well as Boost variety of foreign selection demonstrated increased stress resistance. Yield decrease for these varieties in extreme conditions was 52-63% what is 11-34% lower than that for other studied varieties (Table 3).

TABLE III. PARAMETERS OF ECOLOGICAL FLEXIBILITY OF PERENNIAL RYEGRASS VARIETIES

Variety	Reduced yield in unfavorable conditions,%	Coefficient of ecological flexibility (bi)	Stability coefficient (S^2d)
Malysh (st.)	62	1.13	0.10
Agat	63	0.40	3.77
Bargizmo	82	1.35	0.30
Barimero	82	1.17	0.10
Barcampo	77	-0.88	5.73
Bartasia	74	0.88	0.49
Barfamos	86	1.12	0.63
Boost	52	1.32	2.53

Parameter that shows the reaction norm of a genotype during varying environmental factors is the coefficient of ecological flexibility (bi). The higher this coefficient is (bi> 1), the higher response this variety has. These varieties demand much on cultivation technology. Stability coefficient (S^2d) indicates an adaptive response of the genotype which leads to the correspondence of characteristics changes and properties of the organism with the changes in agro-ecological conditions. They are characterized by the degree of its stability [3].

Coefficient of ecological flexibility of Agat and Bartasia varieties (bi = 0.40 ... 0.88) was less than 1.0, they were characterized by weak response to changes in meteorological and edaphic conditions. Other varieties had a higher response to changes in external factors; their winter hardiness was more susceptible to variability. Negative flexibility coefficient (Barcampo bi = -0.88) shows the instability of this variety, regardless of favorable vegetation conditions. Thus, under relatively favorable conditions in 2016, the yield of this variety was only 0.90 t/ha (in comparison to Malysh standard of 4.72 t/ha), and in unfavorable conditions in 2017, it had an advantage over the standard by 22%.

Malysh and Barimero varieties demonstrated high resistance to changes in agro-ecological conditions (S^2d = 0.10). The combination of ecological flexibility (bi = 1.13) and phenotypic stability (S2d = 0.10) of Malysh variety speaks for its high adaptive properties.

It formed high yield in optimal conditions (4.72 t/ha) and relatively high – in extreme ones (1.31 t/ha). So, this variety

may be classified as ecologically sustainable, namely, medium-intensity variety which can give not very high, but stable yield under any conditions [4].

V. Conclusion

Thus, the assessment of the ecological flexibility of perennial ryegrass varieties on yield level allowed identifying Malysh variety as characterized by the greatest adaptability. On average, over four years of research, this variety was notable for its high winter hardiness of 89.3%.

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