Immunological and adaptive assessment of soybean samples of competitive variety testing in the Amur region

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Abstract. The results of study of the samples of competitive variety testing in the Amur region are presented. The research was carried out in 2018-2020 on experimental plots of the breeding crop rotation of the All-Russian Scientific Research Institute of Soybean. As a result of the phytopathological survey, 12 best highly immune soybean samples were identified, of which the most adaptive (Ka > 1) to the conditions of the region were marked with 5 numbers: Amurskaya 24/42 (Ka = 1, 07), Amurskaya 24/54 (Ka = 1.07) and Amurskaya 24/60 (Ka = 1.11), Alena standard (Ka = 1.05), Amurskaya K-4/23 (Ka = 1.02) and Amurskaya K-14/17 (Ka = 1.05). As a result of a comprehensive assessment, considering the indicators of adaptability, productivity, and resistance to diseases, the 3 best soybean samples were identified: early-ripening – Amur 24/42; medium-ripening - Amur 24/54, Amur 24/60 with a yield of 2.78 (+ 0.46 t/ha to st); 2.80 (+ 0.32 t/ha to st); 2.75 (+0.27 t/ha to st). Two of which Am. 24/60 and Am. 24/42 were transferred in 2020 to the State Variety Testing for 2021-2022 as new highly productive, immune varieties Tisei and Luchistaya.

1 Introduction

One of the most priority agricultural crops is soybean, since it plays an important role in increasing the production of vegetable protein on the planet [1, 2]. In the Russian Federation, the main region of crop cultivation is the Far East, where the Amur region is the leader in terms of the area of sowing and gross grain harvest. In recent years, soybean production has been steadily increasing, and at the same time both due to the expansion of sown areas and increasing its yield [3, 4]. Nevertheless, the productivity of soybean is largely determined by a number of different factors. Among them, meteorological conditions should be noted, which can have both positive and negative effects on the growth and development of plants, as well as on the spread of pathogens [5]. Fungal and bacterial diseases have a huge negative impact on the volume and quality of the soybean crop. The presence of pathogens, their harmfulness and wide prevalence are closely interrelated with climatic and weather conditions, as well as the reaction of the host plant [6]. The limiting factor for the epiphytotic spread of leaf forms of diseases, especially

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caused by phytopathogenic fungi, is an increased amount of uneven precipitation, abundant dew, drizzle, fog [7, 8, 9]. The monsoon-continental climate of the Amur region is characterized by deep winter freezing of the soil, periodic spring-summer droughts, excessive soil moisture in the second half of summer, which creates a favorable background for the development of infectious diseases of soybean [10, 11]. Among the most harmful diseases of soybean in the Amur region there are septoria *(Septoria glycines Hemmi)*, peronosporosis *(Peronospora manshurica Naum.)*, cercosporosis *(Cercospora sojina Hara)*. Recently, bacteriosis *(Bacterium glycineum Coerper)* and phyllostictosis *(Phyllosticta soyaecola Massal)* have become widespread [6, 8, 11].

As it is known, a significant spread of phytopathogens significantly reduces the yield of soybean, therefore, breeding for resistance is perhaps the most important component of the modern breeding process. It has been established that the creation and cultivation of adaptive varieties with complex resistance to diseases is the most dynamic, cost-effective and environmentally safe method of plant protection [12, 13, 14]. The use of highly immune varieties can significantly reduce the use of fungicides, which reduces the chemical load on the environment and financial costs when cultivating soybean [15, 16]. In this regard, a comprehensive study of the immunological and adaptive ability of newly created soybean varieties at the final stages of the breeding process is of particular relevance.

The purpose of the research is to conduct a phytopathological assessment of soybean samples of competitive variety testing to identify the most promising numbers that exceed the productivity standards, have a high adaptive potential and complex resistance to pathogens.

2 Materials and methods

The research was carried out on experimental plots of the breeding crop rotation of the FSBSI FRC All-Russian Scientific Research Institute of Soybean in 2018...2020. The material for the study was samples of soybean of competitive variety testing (CVT) of the Amur breeding of various ripeness groups. The experimental part of the work was carried out in accordance with the technology developed for the southern agricultural zone of the Amur region [7]. Sowing of soybean samples was carried out in 3-fold repetition by the method of randomized repetitions (blocks), the area of plots was 40.5m^2, the accounting area was 32.4m^2. During the entire growing season, phenological observations and field assessments were carried out according to the methodology of the State Variety Testing of agricultural crops [17]. Varietal weedings were performed during the flowering and maturation phases. Cleaning of plots was carried out by continuous threshing.

The yield of varieties was determined based on the standard seed moisture (14%) according to GOST 12041-182 [18]. During the mass flowering period from July 14 to July 30, leaf forms of diseases were determined against the background of the natural spread of infection according to the methodological recommendations of the VIR [19, 20]. The immunological assessment was carried out according to the disease development scale: 0 – immune (N), 1...10% - highly resistant (UU), 11...25% - resistant (U), 26...50% - medium-susceptible (S), 51...75 – susceptible (V), 76...100% – highly susceptible (VV). The percentage of seed damage by diseases was determined by counting the total number of diseased seeds per 1000 pieces.

To assess the adaptive and productive potential of the samples according to the yield indicator, the method of L.A. Zhivotkov et al. was used [21]. The coefficient of adaptivity (Ka) was calculated for each year and soybean sample according to the formula:

$$Ka = (x_{ij} \times 100 : x) : 100 \quad (1)$$

where x_{ij} is the yield of the i–th grade in the j-th year of the test; x is the average varietal yield of the year.

Meteorological conditions during the years of the research differed in temperature and precipitation. In terms of moisture availability, all the growing seasons of 2018-2020 did not meet the norm required for soybean culture, the hydrothermal coefficient (HTC) for the growing season was – in 2018 – 1.94; in 2019 – 2.63; in 2020 – 2.36. Precipitation by months and decades was uneven, so there was both a lack of moisture and an excess of it. The HTC value during the periods of disease observation varied from 0.6 to 3.7 (Table 1).

Table 2. The sum of active temperatures, precipitation and HTC in the southern agricultural zone of the Amur region, (May–July 2018-2020).

year	month	Precipitation amount, mm	Sum of active temperatures, >10°C	HTC
2018	May	25.1	446	0.5
	June	188.2	537	3.5
	July	181.8	691	2.6
	For the period	395.0	1674	2.3
2019	May	66.6	381	1.7
	June	94.4	549	1.7
	July	246.8	660	3.7
	For the period	407.8	1590	2.5
2020	May	72.5	418	1.7
	June	140.0	510	2.7
	July	42.7	747	0.6
	For the period	255.2	1675	1.5

Regarding the soybean crop the HTC (according to G.T. Selyaninov) from 1 to 1.7 characterizes favorable conditions for the growth and development of soybean plants, over 1.7 – waterlogging; 0.8...0.9 - reduced moisture supply; 0.6...0.7 - insufficient; 0.4...0.5 - pronounced drought [22].

3 Results and discussions

As a rule, the species composition of diseases and their development directly depend on agro-climatic conditions, that is, on the temperature and humidity of the growing seasons, so it is important to take these factors into account when evaluating the breeding material [7]. The growing seasons of 2018...2020 were characterized by excessive moisture, which contributed to the significant development of leaf forms of soybean diseases and created a favorable natural infectious background for their spread, but at the same time allowed an objective assessment of the studied material and to identify the most immune forms.

In 2018, 188.2 mm of precipitation fell in June, which is 2.2 times more than the average annual indicator. Heavy precipitation was also in July of this year, when 181.8 mm fell with an excess of 73.8 mm. The warm, rainy weather in July 2018 contributed to the spread of diseases on soybean leaves, but temperature differences and relative humidity restrained the intensity of their development. When assessing the contamination of CVT samples with bacteriosis, the degree of damage to plant leaves was revealed from 2.0 to 11.0 %, with Septoria blight - 7.5...29.5 %. The pathogen damage of false mildew varied from 0.5 to 20.5%, cercosporosis 1.5...16.0 %, phyllosticta leaf spot - 0...9.6 %. The number of diseased seeds in CVT samples ranged from 0.2 to 21.5 %.

In June 2019, 94.4 mm of precipitation fell at a rate of 85 mm, and in July 246.8 mm at a rate of 106 mm - this is 2.3 times more than the average annual indicator. During these periods, there was a strong waterlogging of the soil, which contributed to a significant spread of fungal diseases of soybean. Warm weather with intermittent rains and high relative humidity at the end of July contributed to a significant manifestation of Septoria blight on soybean samples. The disease manifested in the form of rusty spots on the triple leaves of the lower and middle tiers and strokes on the stems (lower part). At the end of the second decade of August, premature leaf fall of the lower tier was observed in soybean samples susceptible to Septoria blight. According to the results of the assessment of the manifestation of bacteriosis on plant leaves, the degree of lesion was 1.5...26.2%, the lesion with Septoria blight was more widespread than with other fungal pathogens and varied from 11.2 to 45.7 %, the lesion with false mildew and cercosporosis was smaller and, respectively, was 0.5...32.0% and 12.5...35.5 %. The plants were least affected by phyllosticta leaf spot - 0...4.5 %, which is significantly lower than the threshold of harmfulness. The number of seeds affected by diseases according to the samples ranged from 3.3 to 25.5 %.

In 2020, in July, there was an increased temperature background with an excess of the average long-term indicator by 2.6^{0}C, with a norm of 106 mm, only 42.7 mm fell during the month, which is 2.4 times lower than the average long-term one. Hot, dry weather restrained the intensity of the development of diseases. Nevertheless, slight precipitation in the form of drizzle and fog in the morning still contributed to the manifestation of mainly Septoria blight and cercosporosis in soybean crops. The level of bacteriosis development on the CVT samples varied from 0.5 to 15.5 %, Septoria blight - 5.5...30.5; false mildew - 0.5...13.5 %; cercosporosis - 5.0...17.5; phyllosticta leaf spot - 0.5...11.5 %. The damage of seeds by diseases varied from 1.5 to 18.7%.

Thus, as a result of a three-year comprehensive phytopathological assessment of CVT samples, it was found that the manifestation of leaf forms of diseases is significantly influenced by weather conditions. The dominant diseases in the years of research were marked by Septoria blight, cercosporosis, phyllosticta leaf spot, the prevalence of which reached 50...80% on individual CVT samples. The highest values of the degree of lesion and the level of spread of Septoria blight, false mildew and cercosporosis were recorded in the wettest July 2019, phyllosticta leaf spot in the relatively dry July 2020. According to the results of a 3-year analysis for resistance to leaf forms of the disease, 12 numbers of CVT soybean with a high immune status were identified (Table 2)

According to the susceptibility to harmful pathogens, all the presented samples were marked mainly as resistant and highly resistant, characterized mainly by a lower degree of damage in comparison with standard varieties of Lydia, Dauria and Alena.

Table 2. Immunological characteristics of the best soybean samples of competitive variety testing, 2018-2020.

Variety, varietal sample	Bacteriosis		Septoria blight		Falsemildew.		Cercosporosis.		Phyllosticta leaf spot.		Seed damage by diseases, %
	d.d., %	i.h.	d.d., %	i.h.	d.d., %	i.h.	d.d., %	i.h.	d.d., %	i.h.	
Early-repining group											
Lydia	14.1	U	29.6	S	19.5	U	23.3	U	2.3	UU	18.2
Amurskaya K-3/87	8.5	UU	18.7	U	10.0	UU	14.1	U	2.8	UU	2.1
Amurska	9.2	UU	19.8	U	3.5	UU	9.4	UU	2.2	UU	7.1

ya 24/42											
Amurskaya 24/63	5.3	UU	23.6	U	7.0	UU	15.1	U	1.8	UU	3.4
Amurskaya 24/64	8.1	UU	18.6	U	6.5	UU	16.1	U	2.7	UU	12.3
Medium-ripening group											
Dauria	19.2	U	25.7	U	12.0	U	20.1	U	3.5	UU	13.4
Amurskaya K-4/28	7.7	UU	16.0	U	8.5	UU	12.9	U	2.3	UU	6.1
Amurskaya 24/54	6.7	UU	24.1	U	2.0	UU	11.0	U	2.2	UU	5.3
Amurskaya 24/60	8.9	UU	21.8	U	3.5	UU	14.0	U	2.5	UU	4.1
Amurskaya K-8/17	7.7	UU	16.7	U	3.0	UU	9.9	UU	2.8	UU	6.2
Late-ripening group											
Alena	12.9	U	20.9	U	5.5	UU	16.3	U	2.8	UU	7.4
Amurskaya K-4/79	13.1	U	22.3	U	11.0	U	19.3	U	2.8	UU	13.8
Amurskaya K-4/43	12.2	U	22.5	U	3.5	UU	20.1	U	2.5	UU	9.9
Amurskaya K-4/23	13.0	U	19.1	U	1.5	UU	14.0	U	2.8	UU	12.3
Amurskaya K-14/17	17.2	U	21.2	U	3.0	UU	10.6	U	1.8	UU	7.9

Note: s.s. – the degree of damage, i.c.-immunological characteristics

The assessment of the damage of soybean samples with Septoria blight over a three-year period under natural conditions showed that the presented samples and varieties showed themselves to be stable according to the immunological characteristics (16.0...25.7%), except for the Lydia standard (29.6% – medium-resistant). The lowest degree of lesion was recorded in the medium-ripening sample Amurskaya K-4/28 (16.0%). The sample Amurskaya 24/63 showed the highest resistance to bacteriosis, the degree of leaf damage was only 5.3%. The lowest percentage of cercosporosis development was observed in the early-ripening group in the Amurskaya 24/42 sample (9.4% - UU), in the medium-ripening group - in the Amurskaya K-8/17 sample (9.9% - UU). The remaining samples and varieties-standards on the scale of disease infestation assessment are marked as resistant - U. Most of the isolated samples showed high resistance to false mildew – UU, with the exception of the standards Lydia, Dauria and the late-ripening sample Amurskaya K-4/79, which were marked as resistant with the development of the disease on the leaves of 11...19.5%. When assessing the development of phyllosticta leaf spot on the leaves of soybean plants, regardless of the ripeness group, all samples and standard varieties showed themselves to be highly resistant, the samples Amurskaya 24/63 and Amurskaya K-14/17 showed the lowest percentage of disease development – 1.8. The analysis of seed damage by diseases allowed to identify three samples of soybean - Amurskaya K-3/87, Amurskaya

24/60 and Amurskaya 24/63 with a minimum percentage of diseased seeds of 2.1...4.1%, in other samples the level of infected seeds ranged from 5.3 to 13.8 %. All samples of the early-ripening and medium-ripening group were marked by a lower percentage of diseased seeds in relation to the standards. The samples of the late-ripening group had a greater number of diseased seeds than the Alena standard by 0.5...6.4 %.

Along with resistance to diseases, newly created varieties should also have a general adaptive ability – to realize potential productivity with annual changes in weather conditions. The coefficient of adaptivity (Ka) allows to really assess the productive and adaptive capabilities of the studied soybean samples in various weather conditions. In our studies, the value of this indicator ranged from 0.89 to 1.17 (Table 3).

Table 3. Seed yield and coefficient of adaptability of soybean samples of competitive variety testing 2018-2020.

Sample name	Yield, t/ha			Average for 3 years, t/ha	Coefficient of adaptability Ka
	2018	2019	2020		
Early-repining group					
Lydia	2.25	2.46	2.26	2.32	0,89
Amurskaya K-3/87	2.34	2.86	2.27	2.49	0,96
Amurskaya 24/42	2.72	2.85	2.78	2.78	1,07
Amurskaya 24/63	2.56	2.66	2.42	2.54	0,98
Amurskaya 24/64	2.47	2.81	2.39	2.55	0,98
Medium-ripening group					
Dauria	2.27	2.66	2.52	2.48	0,95
Amurskaya K-4/28	2.41	2.67	2.55	2.54	0,98
Amurskaya 2454	2.41	2.86	3.14	2.80	1,08
Amurskaya 2460	2.55	2.97	2.74	2.75	1,06
Amurskaya K-8/17	2.63	2.33	2.62	2.52	0,97
Late-ripening group					
Alena	2.50	2.81	2.77	2.69	1,04
Amurskaya K-4/79	2.60	2.44	2.53	2.52	0,97
Amurskaya K-4/43	2.38	2.55	2.55	2.49	0,96
Amurskaya K-4/23	2.52	2.83	2.59	2.65	1,02
Amurskaya K-14/17	2.68	2.38	3.06	2.70	1,05
Average annual	2.48	2.67	2.61	2.58	
LSD_{05}	0.16	0.15	0.14		

On average over three years of study of the 15 soybean numberws – only five (33%) were reported as the most adaptive to the conditions of the region (Ka > 1), one of them belongs to the group of early-ripening Amurskaya 24/42 (Ka = 1,07), two medium-ripening - Amurskaya 24/54 (Ka = 1,07) and Amurskaya 24/60 (Ka = 1,11), three late-ripening: the standard Alena (SC = 1,05), Amurskaya K-4/23 (Ka = 1,02) and Amurskaya K-14/17 (Ka = 1,05).

The evaluation of the productive indicators of the most promising samples showed that only six of them significantly exceeded the standard varieties in yield: four early-ripening varieties – Amurskaya K-3/87, Amurskaya 24/42, Amurskaya 24/63, Amurskaya 24/64 with a yield of 2.49 t/ha (+ 0.17 t/ha to st); 2.78 (+ 0.46 t/ha to st); 2.54 (+ 0.22 t/ha to st); 2.55 (+ 0.23 t/ha to st) and two medium-ripening Amurskaya 24/54, Amurskaya 24/60 with a yield of 2.80 (+ 0.32 t/ha to st); 2.75 (+ 0.27 t/ha to st), respectively.

4 Conclusions

In the process of a comprehensive assessment of soybean samples of competitive variety testing, it was found that during the years of research, soybean plants were mainly affected by pathogens of Septoria blight, false mildew, cercosporosis, phyllosticta leaf spot and bacteriosis were not significant. As a result of complex phytopathological analysis 12 best high-immune samples of soybean were allocated, of which 5 are marked as the most adaptive to the conditions of the region (Ka > 1), one of them belongs to the group of precocious – Amurskaya 24/42 (Ka = 1,07), two medium-ripening – Amurskaya 24/54 (Ka = 1,07) and Amurskaya 24/60 (Ka = 1,11), three late-ripening - standard Alena (SC = 1,05), Amurskaya K-4/23 (Ka = 1,02) and Amurskaya K-14/17 (Ka = 1,05). In terms of productivity, only six samples significantly exceeded the standard varieties in yield by 0.17...0.46 t/ha.

Thus, according to the results of 3 years of competitive variety testing, considering the indicators of adaptability, productivity, resistance to diseases and a combination of economically valuable traits, 3 best soybean samples were identified: Amurskaya 24/42, Amurskaya 24/54, Amurskaya 24/60 with a yield of 2.78 (+0.46 t/ha to st); 2.80 (+ 0.32 t/ha to st); 2.75 (+ 0.27 t/ha to st). Two of which Am. 24/60 and Am. 24/42 were transferred to the State Variety Testing for 2021-2022 as new highly productive, highly immune varieties Tisei and Luchistaya.

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