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ANALYSIS OF RESISTANCE TO *SEPTORIA GLYCINES* IN SOYBEAN WORLD COLLECTION HARVESTED IN SOUTH-EASTERN KAZAKHSTAN

Abstract. The increase of soybean area, yield losses, leads to the search resistant genotypes to common fungal diseases, one of which is brown spot, caused by *Septoria glycines*. In this regard, the analysis of the resistance of the world soybean collection to this disease on the natural infectious background in the conditions of the south-east of Kazakhstan was carried out. The soybean collection consisted from 182 cultivars and lines of different origin from five regions of the world.

As a result of the analysis was shown that 79.3% of the collection is highly resistant and resistant to brown spot. The share of susceptible and highly susceptible samples was 12.1%. The studied collection was also divided into 6 maturity groups depending on the length of vegetation period. The results of a comparative analysis between maturity groups on the basis of resistance revealed that ultra-ripening accessions were more susceptible to brown spot than late-ripening accessions.

The structural analysis identified the economically valuable soybean cultivars and lines. Based on plant height, eighteen accessions that suitable for optimal parameters 95-105 cm were identified. Cultivars Supra, Slavia, Vega were with high yield from maturity group I and registered as the group of highly resistant accessions to brown spot.

Statistical analysis showed a negative correlation between the main economically valuable traits and the resistance to brown spot. The correlations of resistance with plant height and number of fertile nodes were most significant ones. Obtained results are important for breeding program in development of high-yielding soybean cultivars with resistance to brown spot.

Key words: soybean, brown spot, resistance, world collection.

Introduction. Soybean (*Glycine max* (L.) Merrill.) is an important food, feed (protein-oil), technical culture in the world and in Kazakhstan [1]. In the Republic of Kazakhstan according to the program for diversification of agricultural crops, soybean area will expanded to 400,000 hectares by 2020, which should ensure the production of soybeans in the country to 1 million tons [2].

One of the main problems in the cultivation of soybean is fungal diseases [3]. The relationship between resistance to fungal diseases and yield components depends on the level of disease infection, which in turn depends on the species of pathogens in certain agro-climatic zones, the resistance of cultivated lines, agricultural technology and the influence of environmental factors. Some years, the death of the plant can reach practically 100% and the seedlings 37-43% [4, 5].

One of the most common fungal diseases is brown spot, which affects the leaf surface of soybean, covering with brown spots with a yellow band. This fungal disease is common in soybean cultivation area around the world [3, 6]. The causative agent is a fungus from the genus of anamorphic sphaeropsidales fungi-deuteromycetes - *Septoria glycines* Hemmi. At the beginning, small brown spots develop on leaves in the lower tier and then progress up the plant as the season progresses, rising to the middle, and then upper tier. Individual spots may coalesce, and the surrounding tissue becomes chlorotic, with occurrence of premature defoliation [7, 8, 9]. The yield losses associated with *S. glycines* infection ranged from 12 to 17% in fields with a simulated infectious background, and from 1 to 8% on a natural infectious back-

ground [8, 10, 11]. Cooper R.L. *et*.al [12] described a decrease of yield by 40% in irrigated fields in 1980. This trend is associated with an increase in humidity, which is a favorable condition for the spread of fungal diseases [13]. However, sometimes brown spot is considered a non-dangerous disease, with a limited impact on yields [12]. In the United States, yield losses ranging from 0.6 to 2.6% of the total yield were attributed to brown spot during 1999 to 2003 and 2005 [14]. The highest losses reported were in 2004 in the states of Iowa and Illinois, approximately 305.7 thousand tons and 223.8 thousand tons, respectively [14]. The assessment of the level of yield losses is in the range of 8 to 15% and occurs when 25-50% of the leaves fall prematurely. The level of damage by the disease at the stage R6 (full seed), gives a preliminary forecast for yield. The presence of large brown spots on the leaves is usually accompanied by a decrease in the size of the soybean seeds, which in turn affects to the yield [15, 16].

Material and methods. The studied soybean collection consisted from 182 cultivars and lines from the countries of Eastern and Western Europe, North America, East Asia and Kazakhstan (figure 1).

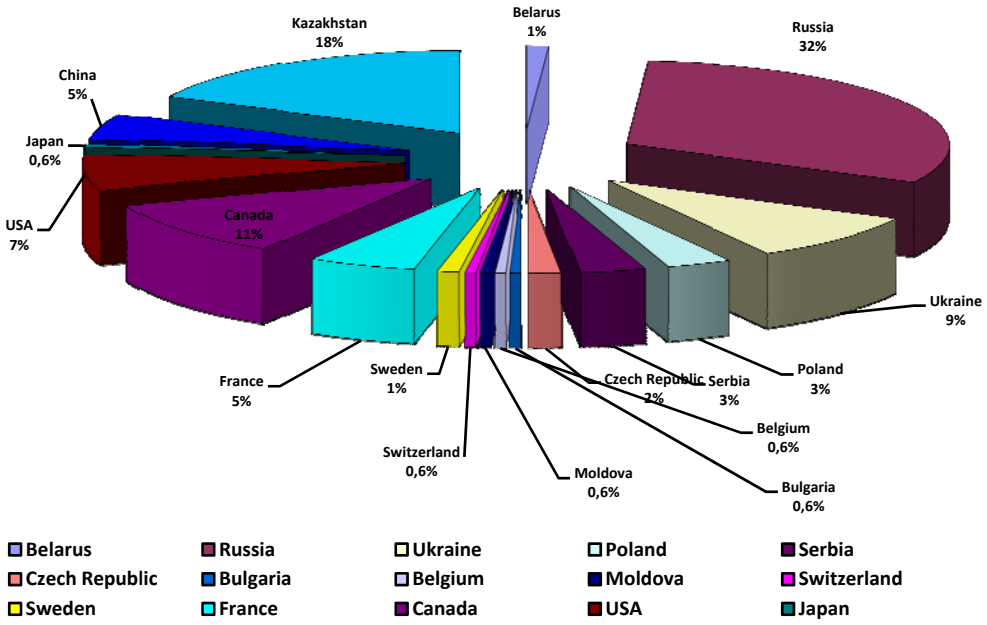

Figure 1 – The collection by the origin country

Plants were grown in 1 meter long rows with 30 cm distance between adjacent rows and 5 cm space between plants within rows [17].

The development of the disease in the field is recorded during the emergence, flowering, beginning and ripening of the seeds. The level of damage or the percentage of development of the disease, is characterized by the number of spots, ulcers, plaque on the affected organs. Quantitative scales for evaluation of the resistance in the field conditions were used. These scales were used both natural and simulated infectious backgrounds. According to the, The internationally recognized classifiers and parameters have as shown in table 1 were applied (figure 2) [18].

Table 1 – Scale of level of damage and resistance to fungal diseases

Degree of defeat	Score on a 9-point scale	Percentage of damage	Letter designation of resistance
absent or very weak	1	0-5%	RR - highly resistant
weak	3	5-19%	R - resistant
medium	5	20-49%	MR - medium resistant
strong	7	50-79%	S - susceptible
very strong	9	< 80%	SS - highly susceptible

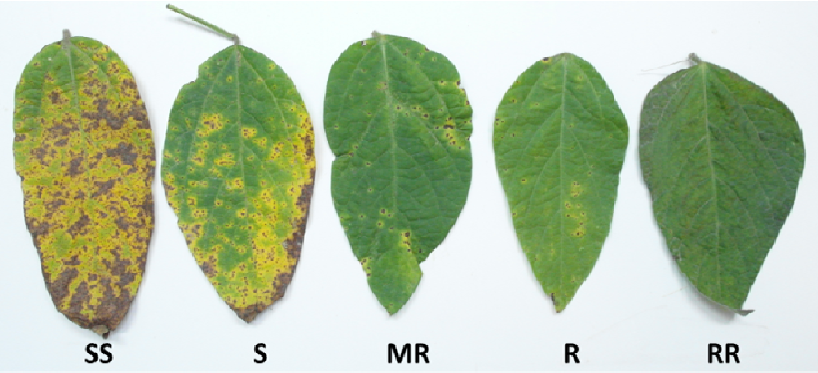

Figure 2 – Scale of soybean resistance to brown spot

Cultivar Vilana from the breeding of the All-Russian Research Institute of Oilseeds was used as a control as it was a highly resistant to brown spot. For comparison of economic-valuable traits, the Zhansaja cultivar (breeding of the KazSRIAP), which was regionalized in the Almaty region, was taken as the standard.

Structural analysis was conducted using methodological guidelines of the State Commission of the Republic of Kazakhstan [19]. During the maturity time, before harvesting the plots, a structural sheaf was selected from the registration sites. In the laboratory analysis the following components of yield were taken into account: plant height, cm - length of stem from the root to the top; number of fertile nodes, pcs. – number of nodes bearing seeds when maturing; number of seeds per plant, pcs. - number of seeds from the plant; yield per plant, g – weight of seeds from one plant; thousands seeds weight, g – weight of thousands seed without any selection [20].

Statistical analysis of the obtained data was carried out using the computer program SPSS16.0 (www.ibm.com/analytics/spss-statistics-software).

Results and discussion. Analysis of resistance to brown spot was carried out in the experimental sites of KazSRIAP on a natural infectious background. Response to lesions causative agents of the disease made it possible to reveal the diversity in the studied collection. Most accessions of the collection have shown themselves to be highly resistant (RR) and resistant (R) (Figure 3, Table 2). A small number of samples showed themselves as susceptible and highly susceptible. The first symptoms of the lesion were observed in stage R1 (budding time). Mass infection of plants was observed at the stage of full seeds (R6).

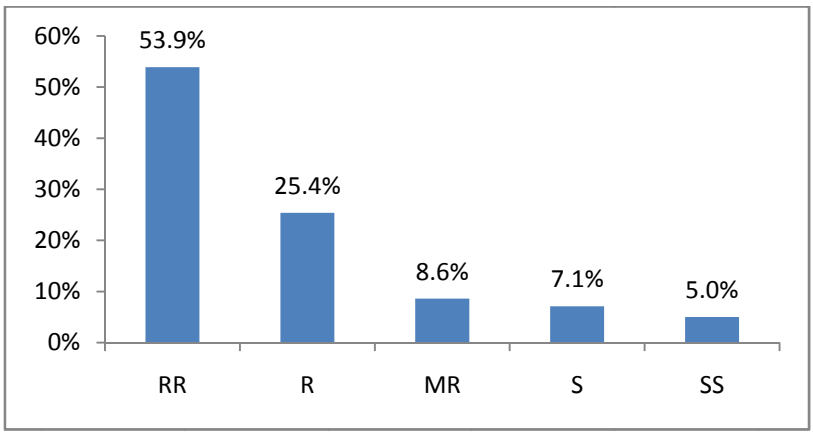

Figure 3 – Diagram of resistance of the world soybean collection accessions to brown spot

During the growth and development of plants, the collection was characterized and divided into maturity groups depending on the length of the vegetation time (Table 3). The most representative was the maturity group OO (57 accessions), the smallest number of accessions (7) was in late maturity group (III).

Table 2 – The world soybean collection by groups of resistance to brown spot

Resistance	Name of cultivars and lines
RR	Jasel'da, Pripjat', Emerson, Supra, Maple Ridge, Mapleglen, Mapleamber, KG 20, AC Brant, Harbin, LMF, Lidija, Luchezarnaja, Zlata, Vega, Zakat, Zernica, Niva 70, Garmonija, Romantika, Belgorodskaja 6, Daksoy, Dawson, Terek, Horol, Jug 30, Estofita, Podjaka, Viktorina, Sepia, Amphor, Toury, Turijskaja masnaja, Oyachi №2, 209/1, 350/1, 362/2, 371/2, Roza, Misula, Almaty, Evans, Lambert, Mc call, Parker, Dekabig, Jachynes Brond, Lara, OAO Wallace, GEO, Buster, SL 01 26, Sl 02 25, RCAT Persian, Enterprise, Voevodzhina, Ana, Nikko, Sava, Venera, Protina, Sponsor, Isidor, Shama, Santana, Lada, Vesta, Vilana, Del'ta, Lan', Runo, Astra, Slavija, Biser 291, Iskra, Zhansaja, Vita, Bolashak, Sabira, Pamjat' JuGK, Jevrika, Sulamit, Kazahstanskaja 2309, Akku, Radost', Nadezhda, Xinjiang a don 1, Xinjiang heihe 38, Xinjiang D09-676, Xinjiang D10-51, Xinjiang D10-130, XinjiangD10-135, Xinjiang D11-252, Lybid', Cheremosh, Korsak, Tanais, Desna
R	R-73-3, Maplearrow, Gaillard, Chabem Wekoju, Kollekcyina, Hejhek 14, Severnaja 5, Soer 3491, Omskaja 4, VNIIS-1, Soer-4, Bara, Zolotistaja, Mageva, Soer-5, Okskaja, Maleta, Svapa, Vejdelevskaja 17, Jantarnaja, Sib NIISHOZ 6, Belor, Gribskaja Kormovaja, Prikarpat'ska 81, Chernovickaja 7, Ustja, Fvour, 186/1, 404/2, 370/2, Zara, Zhalpaksaj, Agassiz, Wilstar 194, Elgin 141, Cobb 266, Zen, Safrfna, Lira, Bystrica 2, Renta, Bukurija, Zispida 641, Perizat, Danaja, Lastochka
MR	OAC Vision, Maplepresto, Rassvet, Nadezhda, VNIIS 2, Luch nadezhdy, Lancetnaja, Soer 345, USHI 6, Kalmit, Rana, Fiskeby III, 173/1
S	Nawiko, Warsawska, Amurskaja 401, Soer-3, Brjanskaja, Sibniik 315, Sonata, Sibirjachka, Jel'dorado, PJeP 26, Krasivaja mechta, Carola, Spritna, Annushka, 422/1, 407/2
SS	Arctic, Kasatka, Smena, Svetlaja, Altom, Fiskeby V, 308/1, 126/1, 261/1

Table 3 – The world soybean collection by maturity groups

Maturity group	Vegetation period	Name of cultivars and lines
OOO	79-85 days	Svetlaja, Soer 5, Kollekcyina, Kasatka, Svapa, SibNIISHZ 6, Nawiko, Zolotistaja, Mageva, Maleta, Zernica
OO	86-95 days	Hejhek 14, LMF, Severnaja 5, Okskaja, Maplepresto, Arctic, Smena, Sibniik315, Sonata, Zakat, Sibirjachka, Jel'dorado, PJeP 26, Annushka, Rana, Fiskeby v, 308/1, Warsawska, Luch nadezhdy, Lancetnaja, Omskaja 4, Brjanskaja, Krasivaja mechta, 350/1, Soer 3, Soer 4, Zlata, Soer 345, 173/1, Chabem Wekoju, Rassvet, Amurskaja 401, Chernovickaja 7, Soer 3491, 126/1, 261/1, OAC Vision, Maple Ridge, Lidija, Bara, Altom, Mapleamber, VNIIS 2, Niva 70, USHI 6, 186/1, 209/1, Gaillard, VNIIS-1, Garmonija, Vejdelevskaja 17, Jantarnaja, Belor, Prikorpat'ska 81, JuG 30, 422/1 (Ivushka), Tanais
O	96-105 days	Nadezhda, Luchezarnaja, Ustja, Kalmit, Fiskeby III, KG20, Oyachi №2, Pripjat', R-73-3, Romantika, Gribskaja kormovaja, Viktorina, Turijskaja masnaja, Mc call, Carola, Daksoy, Lada, Jasel'da, AC Brant, Protina, Belgorodskaja 6, Spritna, Xinjiang a don 1, Toury, Cobb 266, Xinjiang heihe 38, Estofita, 370/2
I	106-115 days	Emerson, Harbin, Podjaka, Vega, Horol, Sepia, 407/2, Lybid', GEO, Renta, Cheremosh, Agassiz, SL 01 26, Slavija, Desna, Supra, Maplearrow, Mapleglen, Buster, Terek, Amphor, 362/2, 404/2, Evans, Enterprise, Bystrica 2, Vilana, Del'ta, Dawson, Lambert, Lira, Iskra, Pamjat' JuGK, Misula, Nikko, Almaty, 371/2, Lan'
II	116-125 days	Zara, OAO Wallace, SL 02 25, Xinjiang D10-51, Amour, Isidor, Safrfna, Xinjiang D11-252, Korsak, Zen, Zhalpaksaj, Elgin 141, Astra, Bolashak, Xinjiang D10-135, Dekabig, Sava, Shama, Biser 291, Danaja, Xinjiang D10-130, Jachynes Brond, Wilstar 194, Perizat, RCAT Persian, Venera, Vita, Xinjiang D09-676, Roza, Voevodzhanka, Vesta, Runo, Parker, Sponsor, Zispida 641, Zhansaja, Lara, Ana, Santana, Bukurija, Sabira
III	126-135 days	Radost', Nadezhda, Sulamit, Kazahstanskaja 2309, Lastochka, Akku, Jevrika

As a result of the analysis of the relationship between the vegetative period and the resistance to brown spot, it was established that early maturity lines are more susceptible to brown spot damage compared with late maturity lines (figure 4). This trend may be related to the climatic conditions of the region, since the temperature regime and the period of vegetation of early maturity lines of the OOO and OO groups are much favorable for the infection by brown spot.

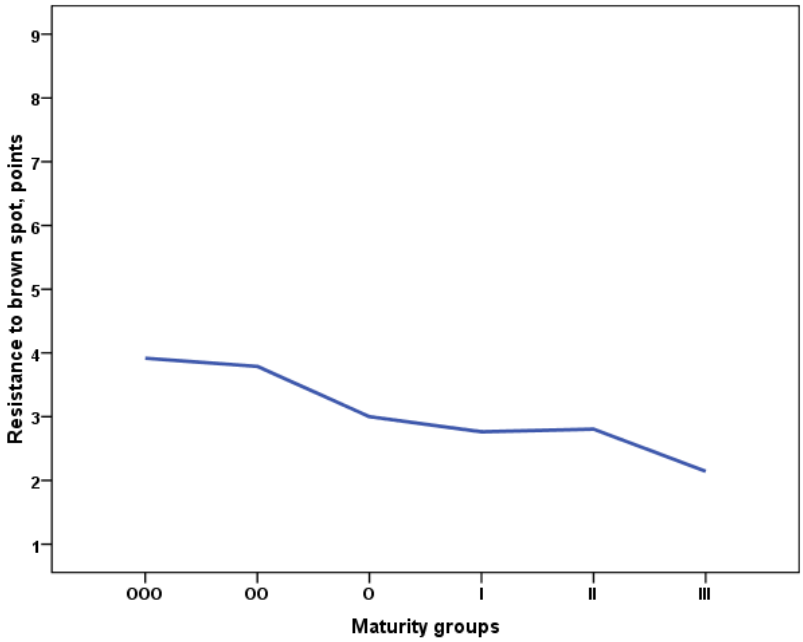

Figure 4 – Resistance to brown spot depending on maturity group

The world collection was studied by morphometric and economically valuable traits. One of the main traits is the plant height. We found that the optimal height at which the best yields showed in the Almaty region is 95-105 cm, since low-growth cultivars are characterized by low attachment of the seeds, and tall ones are prone to lodging, which in both cases leads to a loss of yield when harvesting by combine. Thus, the most optimal plants for this trait were cultivars with medium plant height.

Figure 5 shows the average of plant height by maturity group, as well as the data of the most prominent lines. According to the optimal plant height parameters, 10 samples from the maturity group I were identified with an average plant height of 101.2 cm (figure 5). The list of these cultivars and lines included Nikko, 362/2, Slavia, Buster, Iskra, Delta, Evans, Vilana, Lyra, Podyaka. From the maturity group II, seven samples were selected mainly from Chinese breeding (Santana, Zen, Zara, Xinjiang D10-130, Xinjiang D09-676, Xinjiang D10-135, Xinjiang D11-252), and one cultivar from Kazakhstan breeding (Lastochka) from the maturity group III. It is important to note that there are no accessions suitable for optimum plant height from ultra-maturity groups OOO, OO and O.

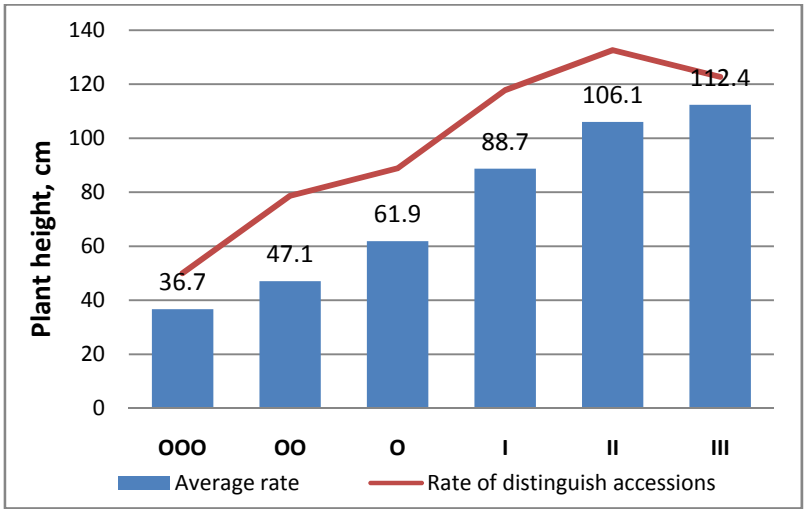

Figure 5 - Characteristics of cultivars and lines of soybean of different maturity groups in the South-East of Kazakhstan in terms of plant height

The number of fertile nodes varied according to the average data from 12.5 pcs from ultra-maturity group (OOO) accessions to 19.8 pcs in the maturity group III accessions (Table 4), with the highest rate for the Supra cultivar - 29.0 pcs, which included in maturity group II. In the standard Zhansai cultivar this trait was 16.1pcs.

On the basis of the number of seeds per plant, the average data varied from 25.8 to 45.3 pcs, depending on the maturity group. The highest rate was in the Slavia cultivar of Russian breeding, 93.7 pcs, which was twice as high as the standard (42.5 pcs).

Average data on the yield per plant varied from 7.5 to 13.2 g. In the Zhansai standard it was 12.1 g. The Canadian cultivar Supra showed the highest result - 23.0 g, which is two time larger than the standard. The smallest result showed the PEP26 (Russia) - 2.5 g, which is 5 times less than the standard.

The thousands seeds weight varied from 150.3 to 175.2 g. This trait characterizes the performance of seeds. In the standard Zhansai cultivar, it was 159.4 g. The lowest result was shown by the cultivar Bystrica 2 (Russia) 90.0 g, the highest result for the cultivar Vega (Russia) 243.0 g.

Table 4 – Structural analysis of economical valuable traits by maturity groups

Maturity group	Number of accessions, pcs	Plant height, cm	Number of fertile nodes, pcs	Number of seeds per plant, pcs	Yield per plant, g	Thousands seeds weight, g
OOO	11	36.7±6.7	12.5±3.0	25.8±7.5	7.9±2.4	171.0±16.4
OO	57	47.1±10.8	12.7±2.9	26.3±6.4	7.5±2.3	171.7±20.5
O	28	61.9±12.3	15.3±3.4	32.8±6.7	9.9±2.6	177.1±23.8
I	38	88.7±15.7	17.4±3.7	40.5±11.7	12.2±3.6	175.2±21.9
II	41	106.1±14.3	17.7±3.1	44.1±10.3	13.2±2.6	165.1±18.1
III	7	112.4±8.3	19.8±4.1	45.3±7.0	12.2±2.1	150.3±28.7

The study of the relationship with the main economic-valuable traits revealed a significant negative correlation with the plant height, the number of fertile nodes and the thousands seeds weight. This correlation based on the thousand seeds weight was noted in previous works [15] on the analysis of resistance to brown spot. At the same time, correlations with the number of seeds per plant and the yield per plant traits were not significant (table 5).

Table 5 – Correlation analysis of economic-valuable traits with resistance to brown spot

Traits	Plant height	Number of fertile nodes	Number of seeds per plant	Yield per plant	Thousands seeds weight	Resistance to brown spot
Plant height	1	0.591**	0.684**	0.648**	-0.194**	-0.164**
Number of fertile nodes	0.591**	1	0.813**	0.766**	-0.049	-0.156**
Number of seeds per plant	0.684**	0.813**	1	0.848**	-0.173**	-0.094
Yield per plant	0.648**	0.766**	0.848**	1	0.036	-0.083
Thousands seeds weight	-0.194**	-0.049	-0.173**	0.036	1	-0.127*
Resistance to brown spot	-0.164**	-0.156**	-0.094	-0.083	-0.127*	1
**Correlation significant $P \leq 0.01$, *correlation significant $P \leq 0.05$.						

It is interesting to note that all values of economically valuable traits correlated positively with each other, except for the thousands seeds weight, which, on the contrary, showed a negative correlation.

Conclusion. In the course of the research carried out on the resistance to brown spot, it was determined that 53.9% of the studied collection (98 accessions from 182 studied) are highly resistant to the disease, from this group it is possible to distinguish the cultivars Iskra, Zhansaja and Sabira, local breeding, on which there were practically no symptoms of disease. Resistant accessions were 25.4% of the collection (46 accessions), 8.6% showed themselves as medium-resistant, which amounted to 16 accessions. The number of susceptible and highly susceptible was 7.1% (13 accessions) and 5% (9 accessions), respectively.

The studied collection was divided into maturity groups. Comparative analysis between maturity groups on the basis of resistance to brown spot revealed a relationship between resistance and maturity. Accessions from ultra-maturity groups are more susceptible to brown spot than late maturity.

Carrying out a structural analysis of the main economic-valuable traits made it possible to identify high-yielding and economically valuable lines. On the basis of plant height, the most optimal parameters were in 10 accessions of maturity group I, 7 accessions of maturity group II, and one accession of maturity group III in the range of 95-105 cm. The cultivar Supra from Canada showed highest number of fertile nodes and yield per plant. The cultivar Slavia (Ukraine) showed the highest number of seeds per plant. The cultivar Vega (Russia) showed highest thousands seeds weight value. All of these cultivars belong to the maturity group I and are highly resistant to brown spot.

Correlation analysis revealed a negative relationship between economically valuable traits and resistance to brown spot. The most significant traits were the plant height and the number of fertile nodes.

Cultivars Iskra, Zhansaja, Sabira, Supra, Slavia and Vega are promising for use in breeding for resistance to brown spot, and carry a variety of genes controlling this trait.

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АНАЛИЗ УСТОЙЧИВОСТИ МИРОВОЙ КОЛЛЕКЦИИ СОИ К СЕПТОРИОЗУ В УСЛОВИЯХ ЮГО-ВОСТОКА КАЗАХСТАНА

Аннотация. Увеличение посевных площадей сои, потери урожая, приводят к необходимости поиска генотипов, устойчивых к распространенным грибковым болезням, одной из которых является септориоз, вызываемый *Septoria glycines*. В связи с этим проведен анализ устойчивости мировой коллекции сои к данной болезни на естественном инфекционном фоне в условиях юго-востока Казахстана. Коллекция сои состояла из 182 сортов и линий различного происхождения из 5 регионов мира.

В результате анализа установлено, что 79,3% коллекции являются высокоустойчивыми и устойчивыми к септориозу. При этом доля восприимчивых и сильно восприимчивых образцов составила 12,1%. Изучаемая коллекция была также разделена на 6 групп спелости в зависимости от длины вегетационного периода. Результаты сравнительного анализа между группами спелости по признаку устойчивости выявили, что ультраскороспелые образцы были более восприимчивыми к поражению септориозом, чем позднеспелые образцы.

Структурный анализ идентифицировал хозяйственно-ценные сорта и линии сои. По признаку высоты растения идентифицированы 18 образцов, подходящие под оптимальные параметры 95-105 см. По основным компонентам урожайности выделились сорта Supra, Славия, Вега из группы спелости I. Они относятся к группе высокоустойчивых к септориозу образцов.

Статистический анализ позволил выявить отрицательную корреляцию между основными хозяйственно-ценными признаками и устойчивостью к септориозу. Наиболее значимыми были корреляции устойчивости и 1) высоты растения и 2) количества продуктивных узлов. В то же время наблюдали положительную корреляцию между хозяйственно-ценными признаками, кроме признака массы тысячи семян. Полученные результаты важны для селекции с целью создания отечественных устойчивых и высокоурожайных сортов сои.

Ключевые слова: соя, септориоз, устойчивость, мировая коллекция.

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ҚАЗАҚСТАННЫҢ ОҢТҮСТІК-ШЫҒЫС ЖАҒДАЙЫНДА СОЯНЫҢ ӘЛЕМДІК ТОПТАМАСЫНЫҢ СЕПТОРИОЗҒА ТӨЗІМІДІЛІГІН ТАЛДАУЫ

Аннотация. Соя егістік алқабының ұлғайтуы, өнімнің азайыуы, саңырауқұлақ ауруларының тарағанына төзімді генотиптердін іздеуіне талап етеді, олардың бірі септориоз, *Septoria glycines* зақымдайды. Осыған байланысты Қазақстанның оңтүстік-шығыс жағдайында сояның әлемдік топтамасының осы ауруға төзімділік талдауы табиғи инфекциалық фонда өткізілді. Соя топтамасы әлемнің әртүрлі 5 аймағынан шыққан 182 сорт және дақылдардан тұрды.

Талдау нәтижесінде, топтаманың 79,3% септориозға өте төзімді және төзімді болып анықталды. Бұл ретте төзімсіз және қатты төзімсіз дақылдардын үлесі 12,1% құрады. Зерттелген коллекция сондай-ақ, вегетациялық кезеннің ұзындығы бойынша, пісіп жетілген 6 топқа бөліңді. Пісіп-жетілу топтар арасындағы төзімділік белгілері бойынша өткізілген салыстырмалы талдау нәтижелері арасында, кеш пісетін дақылдарға қарағанда ультрапісетін дақылдардың септориозбен зақымдалуына тым төзімсіз екені анықталды.

Құрылымдық талдау сояның шаруашылық-құнды сорттары мен дақылдарын анықтады. Өсімдіктің биіктігі бойынша оңтайлы параметрлерге лайық 95-105см сәйкестендірілген 18 үлгілері анықталды. Өнімділіктің негізгі компоненттері бойынша I пісіп жетілетін тобының Supra, Славия, Вега сорттары бөлініп шықты. Олар септориозға өте төзімді дақылдарының тобына жатады.

Статистикалық талдау негізгі шаруашылық-құнды белгілері мен септориозға төзімділігі арасындағы жағымсыз корреляцияны анықтауға мүмкіндік берді. Неғұрлым маңызды корреляция төзімділікпен және 1) өсімдік биіктігі және 2) өнімді тораптар саны бойынша болды. Сондай-ақ, мың тұқым масса белгісінен басқа, шаруашылық-бағалы белгілері арасындағы жағымды корреляция байқалды. Алынған нәтижелер, отандық төзімді және өте өнімді сорттарының алу мақсатында, селекция үшін маңызды.

Түйін сөздер: соя, септориоз, төзімділік, әлемдік топтама.

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