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Оценка коллекционных образцов сои по хозяйственным признакам и структуре листового аппарата

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Приведены результаты изучения хозяйственных признаков и морфологических показателей листьев коллекционных образцов сои, выращенных в условиях Приморского края. Установлено влияние структурных элементов листа на урожайность культуры. Научные исследования выполнялись с 2021 по 2023 г. в лаборатории селекции сои. Стабильные высокие значения урожайности наблюдали у сортов российского происхождения – Приморская 4 (277,1 г/м^2), Бриз (286,4 г/м^2), Приморская 13 (290,7 г/м^2). Крупносемянностью характеризовались 33,3% образцов сои (масса 1000 семян более 190 г). Высокое содержание белка в семенах (более 40%) сформировалось у образцов Киото, Бриз, Приморская 13; масла (более 24%) – Приморская 4, XN 4, Шарм. Крупным размером листовой пластинки характеризовались сорта XN 4 (237,8 см^2) и Бриз (180,7 см^2), мелким – НС Мина (101,3 см^2). Индекс площади листьев (ИПЛ) сортов варьировал от 5,5 до 8,7 м^2/м^2, высокие значения наблюдали у образцов Киото, Шарм, Бриз, XN 4. Максимальное содержание хлорофилла в листьях обнаружено в сортах Хей-хе 4 и Дочь Викинга. Выявлена сильная корреляционная связь продуктивности с индексом площади листа у 58,3% сортов сои. При увеличении площади листовой пластинки сорта снижали продуктивность, корреляция составляла от –0,05 до –0,98. С увеличением количества листьев на растении повышался уровень продуктивности сортов. При увеличении содержания хлорофилла в листьях сои снижалась продуктивность, за исключением двух среднераннеспелых сортов Киото и Хей-хе 4.

Ключевые слова: соя, сорт, коллекция, площадь листа, индекс площади листа, хлорофилл, продуктивность

Evaluation of soybean collection samples on economic traits and leaf apparatus structure

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The results of the study of economic traits and morphological indices of the leaves of collection samples of soybean grown in the conditions of the Primorsky Territory are presented. The influence of leaf structural elements on the crop yield was established. The research was performed from 2021 to 2023 in the Soybean Breeding Laboratory. Stable high yield values were observed in the varieties of Russian origin – Primorskaya 4 (277.1 g/m^2), Briz (286.4 g/m^2), Primorskaya 13 (290.7 g/m^2). 33.3% of soybean samples were characterized by large seeds (1000 seeds weight of more than 190 g). High content of protein in seeds (more than 40%) was formed in the samples Kyoto, Briz, Primorskaya 13; oil (more than 24%) – Primorskaya 4, XN 4, Charm. The large size of the leaf lamina was distinguished in the varieties XN 4 (237.8 cm^2) and Briz (180.7 cm^2), while the small size was observed in NS Mina (101.3 cm^2). Leaf area index (LAI) of the varieties ranged from 5.5 to 8.7 m^2/m^2, with high values observed in the accessions Kyoto, Charm, Briz, and XN 4.

Maximum chlorophyll content in leaves was found in the varieties Hei-he 4 and Doch Vikinga. A strong correlation between productivity and leaf area index was found in 58.3% of soybean varieties. As the leaf lamina area increased, varieties decreased in productivity, the correlation ranged from –0.05 to –0.98. As the number of leaves on the plant increased, the productivity level of the varieties increased. With increasing chlorophyll content in soybean leaves, productivity decreased, except for two medium-early maturing varieties Kyoto and Hei-he 4.

Keywords: soybean, variety, collection, leaf area, leaf area index, chlorophyll, productivity

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INTRODUCTION

Soybean is a common agricultural crop in the Far East. Due to the monsoon climate in the region, the maximum amount of precipitation is observed in the second half of summer, which provides plants with the necessary amount of moisture during critical phases of growth and development (flowering, bean formation and filling, green mass accumulation)[1] [1–3].

Soybean is sensitive to changes in environmental factors, their mismatch with the biological characteristics of the crop reduces its yield level[2] [4, 5].

To increase productivity and improve the quality of soybean yield, it is necessary to have forms and varieties with rational plant morphotypes capable of maintaining the maximum intensity of photosynthesis in different climatic conditions, which determines the yield by 90–95% [6]. The highest and most stable soybean yields can be obtained only in the crops where the formation of optimal leaf area in relation to certain cultivation conditions is observed. It has been established that in many respects the yield depends on the growth rate and duration of active leaf functioning and is closely related to the structure of the leaf apparatus [7, 8]. The leaf area of each variety is formed due to the combination of all its constituent elements, taking into account morphological differences, which is dynamic and constantly changing throughout the growing season [9, 10].

In order to study and identify a number of the issues related to production and physiological processes of soybean, the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki has formed a collection of varieties of various introductions which are subjected to comprehensive evaluation [11–13].

The purpose of the research was to study soybean samples of different origin by economic traits and morphological leaf parameters in the conditions of the Primorsky Territory and to determine the influence of leaf structure elements on the level of crop productivity.

MATERIAL AND METHODS

The research was carried out on the fields of the Soybean Breeding Laboratory of the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki (near Ussuriysk) in 2021–2023.

In 2021 weather conditions were characterized by increased air temperature and lack of

[1]*Mamonova A.G., Semenova E.A., Kamolykh V.O.* Change in the biochemical composition of soybean seeds during cultivation in different environmental conditions of the Far Eastern region // Far East Agrarian Herald, 2015, N 1 (33), pp. 34–39.

[2]*Lopatkina E.F., Ala A.Ya.* Morphophysiological analysis of soybean varieties and hybrids // Specific issues of genetics, biology and physiology of soybean: scientific and technical bulletin. VASKhNIL, Siberian Branch, Novosibirsk, 1977, vol. 7, 8, pp. 66–77.

precipitation. In 2022, the total amount of precipitation exceeded the average annual norms, 2023 differed from the previous year by prolonged periods of excessive moisture and increased temperature background (the average air temperature per month during the growing season of soybean exceeded the average annual values by 1.4–2.3 °C).

Soil of the experimental site was meadow-brown bleached soil with heavy mechanical composition, organic matter content of 2.5% with pH of the soil solution at 5.7.

The objects of research were 12 collection samples of soybeans from the Federal Scientific Center of Agricultural Biotechnology of the Far East named after A.K.Chaiki of two groups of ripeness of different origin: Chinese (He Nong 62, XN 4, Hei-he 4), Serbian (NS Mina), Canadian (0331), American (Kyoto), Ukrainian (Charm), Russian (Doch Vikinga, Briz, Musson, Primorskaya 4, Primorskaya 13).

The experiments were conducted according to the methodology[3]. Cultivation of the crop was carried out in accordance with the agrotechnics adopted for the Primorsky Territory[4]. The seed sowing rate was 500 thousand seeds/ha, the area of one plot was 1.8 m^2. Sowing and harvesting were carried out manually.

Material description, phenological observations, yield estimation and records on the main economically valuable traits were carried out during the growing season of soybean according to the methodological guidelines[5, 6].

The sample size for analysis of leaf morphological parameters and productivity was 10 plants of soybean. Observations, counts and measurements of the elements of plant and leaf structure were carried out in the first ten-day period of August (from the 5th to the 10th day) during the bean filling phase. Leaf area index (LAI), characterizing the ratio of plant leaf area to soil area, was calculated according to the instructions[7].

The average area of the complex (triple) leaf (S_{tl}) was determined on the basis of field photographs of soybean leaves on millimeter paper with subsequent processing of the material in a specially developed program in the laboratory of cell biology and developmental biology of the Federal Scientific Center of the East Asia Terrestrial Biodiversity. The level of chlorophyll content in the leaf plate of soybean varieties was measured using the atLEAF CHL instrument (USA).

Calculation of mean values of the trait with setting the error of the sample mean and correlation analysis of straight-line dependence were performed according to the method of field experiment (see footnote 3) in the program Microsoft Office Excel for Windows.

RESULTS AND DISCUSSION

Duration of soybean vegetation period is one of the main varietal traits of the crop, which determines the possibility of genotype cultivation in certain climatic conditions. During the experiment, the variation of the indicator values depending on weather conditions was observed – in the mid-early maturing group from 102 to 109 days, in the mid-ripening group from 110 to 114 days (see Table 1). The least variation of this trait was observed in the samples Charm, 0331 and He Nong 62.

Lack of moisture, as well as its excess, can significantly reduce crop yields during critical periods of soybean development. The lowest yielding varieties were Doch Vikinga (160.0 g/m^2) and Hey-he 4 (167.3 g/m^2). The maximum values of yield by years were observed in the varieties of Russian selection – Primorskaya 4, Briz, Primorskaya 13. By the weight of 1000 seeds 33.3% of soybean samples were characterized

[3] *Dospekhov B.A.* Methodology of field experiment (with the basics of statistical processing of research results). Moscow: Book on Demand, 2012, 352 p.

[4] *Chaika A.K., Tilba V.A., Moiseenko A.A. et al.* Adaptive and progressive technologies of soybean and corn cultivation in the Far East: method. recommendations. Vladivostok: Dalnauka, 2009, 139 p.

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Табл. 1. Хозяйственные показатели коллекционных сортов сои (среднее за 2021–2023 гг.), $X \pm Sx$
Table 1. Economic indicators of collection soybean varieties (average for 2021–2023), $X \pm Sx$

Variety	Yield, g/m^2	Weight of 1000 seeds, g	Plant height, cm	Period of vegetation, days	Content in the seeds, %	
					oil	protein
Middle-early ripeness group						
Doch Vikinga	160,0 ± 50,9	170,7 ± 8,3	62,9 ± 8,6	102 ± 2,1	23,1 ± 1,3	37,1 ± 1,3
Kyoto	265,3 ± 64,1	198,3 ± 22,5	61,4 ± 19,0	109 ± 6,0	23,8 ± 1,3	41,4 ± 1,3
NS Mina	227,6 ± 87,3	146,3 ± 7,8	70,5 ± 11,8	107 ± 3,0	23,7 ± 1,4	39,0 ± 2,3
Hei-he 4	167,3 ± 55,6	180,0 ± 6,2	46,1 ± 10,4	102 ± 5,3	23,0 ± 1,1	40,1 ± 0,7
Charm	272,2 ± 84,2	166,0 ± 25,2	69,2 ± 14,5	106 ± 1,8	24,4 ± 1,9	37,6 ± 2,6
Middle ripeness group						
Primorskaya 4	277,1 ± 77,0	166,7 ± 11,5	73,8 ± 26,3	110 ± 3,0	24,2 ± 2,1	35,3 ± 0,6
0331	262,3 ± 84,8	175,3 ± 4,6	61,9 ± 18,9	111 ± 1,5	23,7 ± 1,6	38,4 ± 2,6
He Nong 62	227,9 ± 38,0	195,7 ± 14,4	62,3 ± 8,7	110 ± 0,6	23,5 ± 1,7	39,0 ± 2,9
XN 4	181,0 ± 59,3	174,3 ± 9,3	72,0 ± 20,3	114 ± 3,6	24,7 ± 1,7	36,9 ± 3,2
Briz	286,4 ± 68,7	198,3 ± 23,6	63,7 ± 19,0	114 ± 4,0	22,2 ± 1,5	41,0 ± 0,7
Musson	181,3 ± 23,0	162,0 ± 18,4	73,2 ± 26,2	113 ± 2,9	21,9 ± 1,0	40,0 ± 2,0
Primorskaya 13	290,7 ± 75,0	193,3 ± 15,3	74,0 ± 26,3	112 ± 2,1	22,2 ± 1,3	40,8 ± 0,8
$LSD_{0,95}$	52,4	20,7	11,3	4,1	1,1	2,5

by large-seededness, the indicator of which ranged from 193.3 to 198.3, g. The varieties Hei-he 4 and 0331 were stable in this trait.

All varieties in the trial had average plant height, except for the Chinese sample Hei-he 4. Stably high protein content (more than 40%) during three years of study was observed in the samples Kyoto, Briz, Primorskaya 13. Varieties Primorskaya 4, XN 4, Charm were distinguished by oil content (more than 24%).

One of the conditions for the organization of effective breeding is knowledge of the morphophysiological type of the initial forms that are planned to be used in hybridization. Soybean lacks mechanisms to restrain leaf lamina growth and is predisposed to the formation of excessive leaf area, which increases the risk of excessive transpiration and a tendency to lodging of plants.

According to the results of observations, the average area of soybean complex leaf in the studied samples varied by years and ranged from 101.3 to 237.8 cm^2 (see Table 2). Varieties XN 4 (237.8 cm^2) and Briz (180.7 cm^2) were characterized by the largest leaf lamina size, while NS Mina (101.3 cm^2) appeared to be the smallest. Significant variation in the leaf area was present in soybean accessions Charm (± 76.5) and 0331 (± 64.0 cm^2).

With the same value of stem density on the plot (40.3 plants/m^2), the samples Doch Vikinga and Briz formed a greater number of lateral branches compared to the others, which in this case is their varietal peculiarity. The lower density of XN 4 plants did not contribute to the formation of a greater number of additional branches.

The leaf area index (LAI) of the varieties ranged from 5.5 to 8.7 m^2/m^2. The index above 8.0 m^2/m^2 was observed in soybean samples both in the mid-early ripeness group (Kyoto, Charm) and in the middle (Briz, XN 4). In the

Табл. 2. Морфологические показатели листьев и растений сои (среднее за 2021–2023 гг.), $X \pm Sx$
Table 2. Morphological parameters of soybean leaves and plants (average for 2021–2023), $X \pm Sx$

Variety	LAI, m^2/m^2	Number of leaves, pcs ./plant	$S_{тл}$,cm^2	Density of stem stand, plants/m^2	Number of lateral branches, pcs ./plant	Chlorophyll, units
Middle-early ripeness group						
Doch Vikinga	6,3 ± 2,8	11,3 ± 3,6	133,5 ± 14,8	40,3 ± 7,8	2,7 ± 0,6	46,8 ± 4,5
Kyoto	8,5 ± 3,3	12,8 ± 2,1	156,1 ± 45,3	43,0 ± 7,9	0,7 ± 0,3	43,9 ± 1,0
NS Mina	6,1 ± 1,9	13,1 ± 1,7	101,3 ± 12,8	45,0 ± 7,9	1,7 ± 0,6	42,7 ± 3,2
Hei-he 4	6,1 ± 1,8	10,7 ± 1,9	145,2 ± 58,3	41,3 ± 7,6	0,8 ± 0,3	47,6 ± 2,5
Charm	8,7 ± 5,0	11,0 ± 1,0	174,1 ± 76,5	44,0 ± 5,3	0,7 ± 0,4	45,8 ± 3,3
Middle ripeness group						
Primorskaya 4	7,1 ± 2,1	10,5 ± 1,5	170,8 ± 57,4	40,3 ± 5,5	1,3 ± 0,4	42,4 ± 3,9
0331	6,1 ± 2,7	12,7 ± 3,7	131,4 ± 64,0	39,3 ± 6,1	1,3 ± 0,1	44,6 ± 4,3
He Nong 62	5,5 ± 1,3	10,4 ± 1,9	133,7 ± 15,5	39,7 ± 2,3	0,4 ± 0,4	43,0 ± 1,9
XN 4	8,2 ± 0,4	10,6 ± 0,6	237,8 ± 39,6	33,7 ± 8,1	0,5 ± 0,6	41,6 ± 4,1
Briz	8,7 ± 2,3	11,8 ± 1,4	180,7 ± 22,6	40,3 ± 5,5	2,3 ± 0,6	44,5 ± 2,6
Musson	7,7 ± 1,4	12,9 ± 1,3	138,1 ± 25,8	43,3 ± 2,1	0,6 ± 0,3	40,3 ± 5,1
Primorskaya 13	7,9 ± 2,4	11,2 ± 0,9	163,5 ± 53,4	44,0 ± 5,3	1,5 ± 0,3	40,1 ± 2,0

Note. LAI – leaf area index; $S_{тл}$ – compound leaf average area.

previously conducted studies in the conditions of the Primorsky Territory typical results were obtained on another set of soybean varieties[8], the variation of this trait was 6.0–8.0 m^2/m^2.

The difference in the number of leaves per plant was insignificant and amounted to 10.4–13.1 pieces. Chlorophyll content in the leaves of the middle-early soybean group was higher than that of the medium-ripening group. The maximum value of chlorophyll was formed in the leaves of Hei-he 4 and Doch Vikinga varieties.

A search for relationships between the values (see Table 3) was performed to establish the influence of the plant and leaf structure elements on the formation of productivity of soybean varieties.

Table 3 shows the variation of the correlation index over the test period, the value of which did not significantly change by years. The result of the correlation analysis revealed a strong direct reliable relationship between the productivity and the leaf area index in 58.3% of soybean varieties, negative strong dependence was observed in XN 4. It was found that the productivity of soybean varieties positively depended on the number of leaves, which changed in a greater direction with increasing plant height. The opposite phenomenon was characteristic of the Serbian variety NS Mina. Basically, soybean varieties decreased productivity with increasing leaf lamina area, there was an inverse correlation with different level of relationship (from -0.05 to -0.98), except for the variety 0331, the value of productivity of which increased with the formation of leaf lamina of a larger size. It should be noted that the level of productivity of middle-early ripeness group varieties decreased to a lesser extent.

The formation of productivity level depending on the number of lateral branches occurred individually for each variety, which reacted differently to the increase/decrease in the number

[8] *Vashchenko A.P., Mudrik N.V., Fisenko P.P., Dega L.A., Chaika N.V., Kapustin Y.S.* Soybean in the Far East. Vladivostok: Dalnauka, 2014, 435 p.

Табл. 3. Коэффициенты корреляции (r) между продуктивностью и элементами структуры растения и листа сои, 2021–2023 гг., r_{min}–r_{max}

Table 3. Correlation coefficients (r) between yield and elements of plant and soybean leaf structure, 2021–2023, r_{min}–r_{max}

Variety	LAI	Number of leaves	$S_{тл}$	Number of lateral branches	Chlorophyll
Middle-early ripeness group					
Doch Vikinga	0,54…0,92	0,37…0,52	0,06…0,10	–0,89…–0,96	–0,19…–0,49
Kyoto	0,97…1,00	0,34…0,60	–0,13…–0,31	–0,77…–0,90	0,40…0,71
NS Mina	0,00…0,07	–0,52…–0,78	–0,05…–0,32	–0,87…–0,98	–0,67…–0,93
Hei-he 4	0,42…0,69	0,92…1,00	–0,25…–0,43	0,00…–0,04	0,98…1,00
Charm	0,94...1,00	0,97…0,99	–0,16…–0,41	0,21…0,46	–0,71…–0,86
Middle ripeness group					
Primorskaya 4	0,97…1,00	0,21…0,46	–0,10…–0,23	0,00…0,04	–0,59…–0,71
0331	0,82…0,96	0,72…0,93	0,53…0,70	–0,50…–0,74	–0,90…–0,98
He Nong 62	0,72…0,91	0,91…0,98	–0,92…–0,98	0,81…0,93	–0,77…–0,95
XN 4	–0,87…–0,98	0,93…0,98	0,07…0,11	0,66…0,92	–0,68…–0,73
Briz	0,93…1,00	0,89…0,96	–0,62…–0,79	–1,00…–1,00	–0,93…–0,99
Musson	0,95…0,99	0,36…0,50	–0,62…–0,85	0,00…–0,07	–0,81…–1,00
Primorskaya 13	0,61…0,89	0,98…1,00	–0,42…–0,53	–0,94…–1,00	–0,96…–0,99

of additional branches. Inverse correlation with a complete connection by years was characteristic of the variety Briz. When the chlorophyll content of soybean leaves increased, productivity decreased, except for two mid-early maturing varieties Kyoto and Hei-he 4.

CONCLUSION

High yield values were observed in soybean varieties of the Russian selection (Primorskaya 4, Briz, Primorskaya 13). Large seeds (1000 seeds weight index of more than 190 g) were distinguished in 33.3% of soybean samples. High content of protein in the seeds (more than 40%) was formed by the varieties Kyoto, Briz, Primorskaya 13; oil (more than 24%) by Primorskaya 4, XN 4, Charm. The average area of complex leaf of soybean samples varied by years from 101.3 to 237.8 cm^2. The largest size of leaf lamina was characteristic of the varieties XN 4 and Briz, small size was typical of NS Mina. Leaf area index above 8.0 m2 / m2 was observed in soybean samples in the medium-early ripeness group (Kyoto, Charm) and medium (Briz, XN 4). The maximum chlorophyll content was formed in the leaves of the varieties Hei-he 4 and Daughter of Viking. A strong direct correlation between productivity and leaf area index was found in 58.3% of soybean varieties. Soybean productivity positively depended on the number of leaves. The varieties decreased productivity with increasing plant leaf area (r r ranged from –0.05 to –0.98) and chlorophyll levels in soybean leaves.

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