RESEARCH OF ECOLOGICAL ASSESSMENT OF MEDIUM-RATING AND MEDIUM-LATE-RATING SOYBEAN VARIETIES

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Abstract. Medium-ripe soybean varieties in the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2021 are represented by 31 varieties. Drought resistance of medium-ripe soybean varieties was 6-9 points. The most drought-resistant varieties were Sandina, Panonka, ES Pallador, and the least drought-resistant were Valentia, KSB 938 – 6 points each, Poltava – 7 points. The seed yield of medium-ripe soybean varieties is 18.0–34.6 c/ha. The most productive varieties were ES Pallador – 34.6 kg/ha, Stein 14F06 – 34.1 kg/ha, Stein 17Zh32 – 33.6 kg/ha, Stein 15I63, Stein 13Zh23 – 32.6 kg/ha, Amphora – 32.0 c/ha. The lowest yields were Banjo KS – 18.0 c/ha, SG Ayder, Morevia – 20.0 c/ha, Irina – 20.1 c/ha, Valentia – 20.2 c/ha, Kent – 20.4 c/ha. Saidin soybean varieties had the highest protein content in seeds – 42.1%, Amphora, Stein 17Zh32 – 41.6% each, Banjo KS, SG SR Picor – 41.5% each, Stein 11X02 – 41.4%. Apollo varieties had the lowest protein content in seeds – 34.0%, Valentia – 35.7%, Masha – 36.0%, Vasylkivska – 36.1%. The highest fat content in the seeds had medium-ripe varieties of soybean Valentia – 24.3%, Vasylkivska – 23.5%, Tena – 23.4%, Apollo – 23.2%. The least fat was contained in the seeds of varieties Stein 17Zh32 – 19.9%, EC Pallador, Stein 14F06 – 20.2%. Medium-late soybean varieties in the State Register of plant varieties suitable for distribution in 2021 included only 4. The most drought-resistant variety was Svyatogor – 9 points, other varieties had a drought resistance score of 8. The most productive was soybean variety Stein 20F26 – 29.4 kg/ha. The lowest yields were Svyatogor – 22.6 c/ha and Kristina – 22.7 c/ha. The highest protein content was in the seeds of Ananda – 39.7% and Christina –

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39.0%, and the lowest – in the variety Svyatogor – 37.3%. The highest fat content – 22.0% had the variety Ananda, and the lowest fat content was the varieties Christina – 20.7% and Stein 20F26 – 20.9%.

1. Introduction

Soybeans are the main legume in Ukraine. In 2020, its sown area exceeded 1 million hectares. However, despite significant achievements of domestic and foreign selection, the average yield of this crop for the last 5 years did not exceed 16.8 c/ha. One of these reasons is the use in the production of varieties that do not meet certain soil and climatic conditions. This applies mainly to introduced varieties that are insufficiently adapted to the soil and climatic conditions of Ukraine. Also, the varieties that are grown, do not always ripen in favorable weather conditions, and harvest dates often coincide with the autumn deterioration of weather conditions, which leads to crop losses from delayed harvesting, shedding and, consequently, reduced marketable and sowing qualities of grain. Harvesting soybean crops with high humidity impairs the cleaning and storage of products, requires additional drying costs. Among the many factors that affect the level of yield, the decisive role belongs to the variety. The level of its resistance to adverse conditions depends on the complex of its adaptive traits, which are under clear genetic control [12].

Natural plant resources – objects of flora that are used or can be used to meet consumer needs [1; 22; 24]. Variety, as an object of intellectual property, is one of the important means of increasing the productivity of agricultural crops. It is the State Scientific and Technical Examination of Plant Varieties that envisages the transformation of a variety from a biological object into a special form of intellectual property, which acts as a commodity on the market of varieties and seeds. Definition Criteria for protection of the variety is the initial stage of market circulation of the variety, the regulation of relations between its author (breeder), producer and consumer. Therefore, varietal plant resources reflect the state of the needs of agriculture, forestry and utilities, as well as food, processing and pharmaceutical industries varieties and hybrids of all groups crops.

Implementation of selection programs aimed at creating varieties of crops with high and stable levels of grain productivity requires the study of genotypic differences and selection on this basis of the source material for plasticity and stability (homeostatic) manifestation of economically valuable features of the plant. The problem of sustainable yields is acute for crops such as soybeans. It is known that changes in soybean growing conditions can significantly affect not only the form of a particular quantitative morphological trait, but also the nature of its connection with other traits, which can cause significant differences between varieties in final grain yield. One of the ways to solve the problem of expanding soybean acreage is to create and distribute varieties adapted to specific soil and climatic conditions of cultivation [23], as well as the mastery of agricultural producers with the latest technologies of its production [24]. It should be noted that one of the most affordable ways for farmers to reduce the negative impact of environmental factors that limit the level of soybean yield is the selection of varieties whose plasticity is most appropriate for a particular area of cultivation.

The growing season of soybean varieties is due to them genetic features. However, both the general growing season of soybean varieties and the interphase period depend on the influence of weather conditions of research years and technological factors which include the sowing period according to soil temperature and seeding rates [1-3]. The early spring of recent years causes intense warming of the soil and promotes the sowing of all crops, including soybeans. The need for early sowing of soybeans is due to the fact that it does not lose moisture from the top layer of soil and get a friendly and full-fledged seedlings. However, under such conditions, the possible return of spring frosts and insufficient heat and light affect the duration of the sowing season, seedlings, the first trifoliate leaf and budding. Therefore study the duration of interphase periods of soybean varieties when sowing at different soil temperatures and sowing rates under climate change remains relevant.

2. Analysis of recent research and publications

In Ukraine, soybeans have not yet acquired such a strategic and important importance, and only in some areas it is grown mainly for grain. However, it has not reached large volumes to solve the problem of protein, such as in the United States, China, Brazil, Italy and other countries, where its production and efficient use in animal husbandry are growing rapidly. Throughout human history, soybean use has changed. Now there are four areas of its use: technology industrial processing of soybeans (soybean meal, full-fat oil); use of soy protein in animal husbandry (feed and meal); processing and use of soy food protein (grain, unripe grain; soybean oil, flour, cereals, coffee, sprouts, sauce, milk, cream, okara, To-fu cheese, meat); use in medicine (folk, official)Soybeans are one of the main protein and oil crops with a wide range of applications: food, feed, technical and medical. Given the high nutritional value and protein content, soybeans have been identified by UNESCO as a strategic food crop [2; 3; 40].

From an agronomic point of view, soybeans are a very valuable crop. As a plant nitrogen fixer, it enriches the soil with nitrogen, improves its structure, is a valuable precursor for cereals, both winter and spring crops, potatoes, corn and others [1; 42].

As predicted by M. Vavilov, soybeans, sooner or later, will take a leading place in the agriculture of our country. After all, the phenomenon of this culture is that it during the growing season synthesizes two crops of protein (38-42%, and in some cases up to 50-52%), fat (18-23%) and almost all organic matter, which is in the plant world, namely: carbohydrates, enzymes, vitamins and minerals (25-30%). In addition, soy protein in chemical composition and amino acid content is close to animal proteins, and in digestion – to milk casein [27].

Soy is one of the most valuable legumes. This culture has acquired such a global significance due to its unique biochemical composition, the associated multifunctional use and high profitability of production [6]. Soy contains everything what a person needs: essential amino acids, vitamins, food minerals, phospholipids. Its amino acid composition corresponds to beef of the highest category. Soya is present in almost all segments of the food complex.

In European countries, 100 kg of soybeans are consumed per person per year [8]. The practical use of the richest potential of soybean should be carried out through its wide involvement in agricultural production [9]. To obtain high and stable soybean yields, along with improving the varietal composition, it is necessary to take into account the biological characteristics of this crop and, through the use of agrotechnical measures, create optimal conditions for realizing the potential of its productivity [10].

The growth of soybean acreage and gross harvest in Ukraine in recent years largely requires the introduction into agriculture of new, adapted to specific soil and climatic conditions, with high resistance to adverse environmental factors, high-tech varieties. Modern soybean varieties, in addition to high yields, should be characterized by high protein and fat content, optimal length of growing season, resistance to diseases, pests and other adverse environmental factors, manufacturability, ability to capture significant amounts of symbiotic nitrogen [19].

An important task of modern soybean varieties is their high adaptability to adverse factors and the ability to maximize their productivity potential in combination with high seed quality [32–33].

Ukraine has a rather large assortment of soybeans of different ripeness groups: ultra-early, early-ripening, medium-early-ripening, medium-ripening and medium-late-ripening. In conditions of intensive agriculture with extreme weather conditions, it is important to grow several varieties of different maturity groups in farms [34].

Medium-ripe soybean varieties have a growing season of 126-135 days and can be a complementary component of soybean varieties when grown in the forest-steppe and steppe of Ukraine, and medium-late varieties with a growing season of 136-145 days – a mandatory component for the steppe [44].

The yield potential of medium-ripe and medium-late soybean varieties is 40–50 c/ha and is the highest among other groups of soybean ripeness in Ukraine. However, the share of this group of varieties in the crops of Ukrainian farmers is not more than 20%. The yield potential of modern soybean varieties is used only by 35-50%. To fully realize the potential of medium-ripe and medium-late soybean varieties, it is necessary to conduct a comparative assessment of environmental, technological, productivity and quality of the crop, which determines the relevance of research [5].

3. Conditions, objective and methods of research

The purpose of the study is to analyze the data of the State Register of Plant Varieties of Ukraine suitable for distribution in 2021, medium and medium late varieties of soybean plants in terms of environmental friendliness, cultivation, resistance to adverse growing conditions, yield and protein and fat content in seeds. will recommend to recommend for growing the optimal medium-ripe and medium-late soybean varieties on a set of indicators.

Today, soybeans are a strategic crop for Ukraine, whose grain exports are more than 1 million tons per year. Unlike other market-oriented crops, soybeans help to improve soil fertility, increase crop yields within crop rotation. In addition, soybeans have universal use and play an important role in improving the economic efficiency of production.

Studies on the ecological assessment of medium and medium late soybean varieties were conducted on the basis of the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2021 [6] and the Official Descriptions of Plant Varieties and Suitability Indicators presented in the Bulletins «Protection of Plant Variety Rights», placed in the Information and reference system «Variety» [7–11].

Soybean varieties, according to the state qualification examination, to determine the suitability for distribution in Ukraine, in particular, are assessed by seed yield, resistance to disease, adverse weather conditions, including drought, plant lodging and seed shedding [11]. In particular, the resistance to the most common soybean diseases was assessed: Peronospora manshurica Sydow, ascochytaso (*Ascochytaso jaecola Abramov*), bacteriosis (*Pseudomonas savastonoipv. Glycinea*), septoria (*Septoria glycines T.*).

The relative resistance of soybean varieties to disease, drought, lodging and seed shedding is determined by a nine-point scale (1-9 points), with 9 points corresponding to the highest resistance and 1 point to the lowest. The following gradation is used: 9 points – excellent stability; 7 points – stability of good; 5 points – stability is satisfactory; 3 points – poor stability; 1 point – stability is very poor [11].

Indicators for the ecological assessment of soybean varieties are established in accordance with the Methodology of examination of plant varieties of cereals, cereals and legumes for suitability for distribution in Ukraine. The experiments were performed on plots of 10–25 m^2 four times [11].

The height of soybean plants is determined before harvesting in two non-adjacent replicates. The height of attachment of the lower beans – by measuring the distance from the soil surface to the place of attachment of the lower beans in 25 plants [11].

Determination of resistance of soybean varieties to major diseases was performed by the percentage of affected plants, in accordance with the requirements of the method [11], drought resistance was determined based on visual assessment of plants during the growing season. Comparisons of the studied indicators were made on the basis of mathematical-statistical correlation-regression analysis.

4. Indicators of manufacturability of medium-ripe soybean varieties

Medium-ripe soybean varieties in the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2021 are represented by 31 varieties. The height of attachment of the lower beans of soybean varieties of this maturity group is 12–21 cm. – 17 cm. The lowest attached lower beans in soybean varieties Kent, Amphora, Malaga, Banjo KS, Olbia – 12 cm (Table 1).

The height of plants of medium-ripe soybean varieties is 68-108 cm. The highest varieties were Moravia – 108 cm, Masha – 101 cm, SG Eider – 95 cm, ES Pallador – 94 cm and Apollo – 93 cm. The lowest were varieties Zlatoslav – 68 cm, Amphora – 73 cm, Banjo KS – 74 cm and SG SR Picor – 75 cm.

Resistance to lodging of medium-ripe soybean varieties is 7-9 points. The highest resistance to lodging was observed in the varieties Masha, Irina, KSB 938, Kent, Amphor, Malaga, SG SR Picor, Saidina, Tena, and the lowest – Olvia, Stein 15I63 and Stein 13Zh23.

Resistance to shedding of seeds of medium-ripe soybean varieties is 6-9 points. The highest resistance was observed to the varieties Masha, Irina, KSB 938, Kent, Rhapsody, Amphor, Malaga, Biser, SG SR Picor, Saidina, Zlatoslava and NS Aurora. The least resistant to seed shedding was the Valentia variety. Other soybean varieties had a seed drop resistance score 8.

Drought resistance of medium-ripe soybean varieties was 6-9 points. The most drought-resistant varieties were Sandina, Panonka, ES Pallador, and the least drought-resistant were Valentia, KSB 938 – 6 points each, Poltava – 7 points.

5. Agroecological stability, yield and seed quality of medium-ripe soybean varieties

Resistance to diseases of the studied soybean varieties was 7-9 points. The most resistant to diseases were the varieties NS Vulcan, Masha, Irina, KSB 938, Kent, Rhapsody, Malaga, SG Ayder, SG SR Picor, Saidina, Feeria, Zlatoslava, NS Aurora, Sava, Tena, Olvia, Panonka, ES Pallador, Stein 11H , Stein 14F06, Stein 17Zh32, Stein 15I63, Stein 13Zh23, and the least resistant varieties are Vasylkivska and Apollon (Table 2).

Table 1

Indicators of manufacturability of medium-ripe soybean varieties

Varieties	Duration of the growing season, days	Height of attachment of the lower bean, cm	Plant height, cm	Resistance to lodging, score	Resistance to seed shedding, score
Valentia	126	14	80	8	6
Vasylkyvska	128	16	90	8	8
Poltava	130	16	82	8	8
NS Vyulkan	133	17	86	8	8
Masha	130	20	101	9	9
Iryna	130	16	82	9	9
KSB 938	130	21	80	9	9
Moravia	128	13	108	8	8
Cent	130	12	80	9	9
Rapsodia	126	13	84	8	9
Amfor	127	12	73	9	9
Malaha	130	12	85	9	9
Biser	126	14	80	8	9
Banjo KS	126	12	74	8	8
SG Aider	130	14	95	8	8
SG SR Picor	130	13	75	9	9
Saidina	130	14	78	9	9
Feeria	128	14	78	8	8
Zlatoslava	130	13	68	8	9
NS Aurora	130	16	87	8	9
Sava	129	18	82	8	8
Tena	130	17	88	9	8
Olvia	131	12	86	7	8
Panonka	127	15	89	8	8
ES Palador	133	17	94	8	8
Staine 11H02	128	15	84	8	8
Staine 14F06	130	17	86	8	8
Staine 17G32	128	14	85	8	8
Staine 15I63	128	14	83	7	8
Staine 13G23	128	14	83	7	8
Apolon	130	15	93	8	8

Table 2

Indicators of agri-environmental stability, yield and seed quality of medium-ripe soybean varieties

Varieties	Drought resistance, score	Resistance to diseases, score	Seed yield, c/ha	Protein content in seeds, %	Fat content in seeds, %
Valentia	6	8	20,2	35,7	24,3
Vasylkyvska	8	7	22,0	36,1	23,5
Poltava	7	8	25,7	39,2	22,4
NS Vyulkan	8	9	23,1	37,1	22,8
Masha	8	9	22,3	36,0	22,2
Iryna	8	9	20,1	39,0	20,6
KSB 938	6	9	25,0	39,8	20,9
Moravia	8	8	20,0	41,0	21,2
Cent	8	9	20,4	40,6	21,1
Rapsodia	8	9	24,1	38,4	21,6
Amfor	8	8	32,0	41,6	20,5
Malaha	8	9	22,5	38,5	21,0
Biser	8	8	25,0	41,0	20,5
Banjo KS	8	8	18,0	41,5	21,8
SG Aider	8	9	20,0	41,0	22,0
SG SR Picor	8	9	23,1	41,5	20,9
Saidina	9	9	24,1	42,1	21,6
Feeria	8	9	22,2	40,3	22,3
Zlatoslava	8	9	21,7	38,9	22,2
NS Aurora	8	9	24,1	39,5	22,8
Sava	8	9	24,8	39,5	22,0
Tena	8	9	28,0	37,8	23,4
Olvia	8	9	29,7	38,8	20,6
Panonka	9	8	25,2	39,3	22,2
ES Palador	9	8	34,6	39,8	20,2
Staine 11H02	8	9	28,5	41,4	20,8
Staine 14F06	8	9	34,1	39,7	20,2
Staine 17G32	8	9	33,6	41,6	19,9
Staine 15I63	8	9	32,6	41,0	21,0
Staine 13G23	8	9	32,6	39,1	20,8
Apolon	8	7	21,8	34,0	23,2

The seed yield of medium-ripe soybean varieties is 18.0-34.6 c/ha. The most productive varieties were ES Pallador – 34.6 kg/ha, Stein 14F06 – 34.1 kg/ha, Stein 17Zh32 – 33.6 kg/ha, Stein 15I63, Stein 13Zh23 – 32.6 kg/ha, Amphora – 32.0 c/ha. The lowest yields were Banjo KS – 18.0 c/ha, SG Ayder, Morevia – 20.0 c/ha, Irina – 20.1 c/ha, Valentia – 20.2 c/ha, Kent – 20.4 c/ha.

Saidin soybean varieties had the highest protein content in seeds – 42.1%, Amphora, Stein 17Zh32 – 41.6% each, Banjo KS, SG SR Picor – 41.5% each, Stein 11X02 – 41.4%. Apollo varieties had the lowest protein content in seeds – 34.0%, Valentia – 35.7%, Masha – 36.0%, Vasylkivska – 36.1%.

The highest fat content in the seeds had medium-ripe varieties of soybean Valentia – 24.3%, Vasylkivska – 23.5%, Tena – 23.4%, Apollo – 23.2%. The least fat was contained in the seeds of varieties Stein 17Zh32 – 19.9%, EC Pallador, Stein 14F06 – 20.2%.

6. Indicators of manufacturability of medium-late soybean varieties

Only 4 medium-ripe soybean varieties have been included in the State Register of Plant Varieties Suitable for Distribution in 2021. Among them, the lower beans in Svyatogor – 18 cm and Kristina – 17 cm are the highest, and the lowest – in Ananda – 15 cm and Stein 20F26 – 16 cm. The highest varieties were Svyatogor – 101 cm and Christina – 94 cm, and the lowest – Ananda and Stein 20F26 – 86 cm (Table 3).

Table 3

Indicators of manufacturability of medium-late soybean varieties

Varieties	Duration of the growing season, days	Height of attachment of the lower bean, cm	Plant height, cm	Resistance to lodging, score	Resistance to seed shedding, score
Svyatogor	145	18	101	9	9
Kristina	144	17	94	9	9
Anada	137	15	86	8	9
Stain 20F26	137	16	86	8	8

Resistance to lodging in the varieties Svyatogor and Kristina was the highest – 9 points each, and in the varieties Ananda and Stein 20F26 –

8 points each. The Stein 20F26 variety had the lowest resistance to seed shedding – 8 points, and the other varieties had a resistance of 9 points.

The most drought-resistant was the medium-late variety Svyatogor – 9 points, the other varieties had a drought resistance score of 8. All medium-late varieties of soybeans were highly resistant to diseases with a resistance score of 9.

7. Indicators of agro-ecological stability, yield and seed quality of medium-late soybean varieties

The most productive was the medium-late soybean variety Stein 20F26 – 29.4 kg/ha. The lowest yields were Svyatogor – 22.6 c/ha and Kristina – 23.7 c/ha (Table 4).

Table 4

Indicators of agro-ecological stability, yield and seed quality of medium-late soybean varieties

Svyatogor	Drought resistance, score	Resistance to diseases, score	Seed yield, c/ha	Protein content in seeds, %	Fat content in seeds, %
Kristina	9	9	22,6	37,3	21,2
Anada	8	9	23,7	39,0	20,7
Stain 20F26	8	9	25,4	39,7	22,0
Svyatogor	8	9	29,4	38,6	20,9

The highest protein content was in the seeds of Ananda – 39.7% and Christina – 39.0%, and the lowest – in the variety Svyatogor – 37.3%. The highest fat content – 22.0% had the variety Ananda, and the lowest fat content was the varieties Christina – 20.7% and Stein 20F26 – 20.9%.

8. Correlation-regression analysis of the study

A strong negative correlation was found between the protein and fat content in the seeds of medium-ripe soybean varieties (r = – 0.665), ie the higher the protein content in the seeds of medium-ripe soybean seeds, the lower the fat content.

The regression equation, the coefficient of determination (R^2) and the diagram of the relationship between protein and fat content in the seeds of medium-ripe soybean varieties are presented in Figure 1.

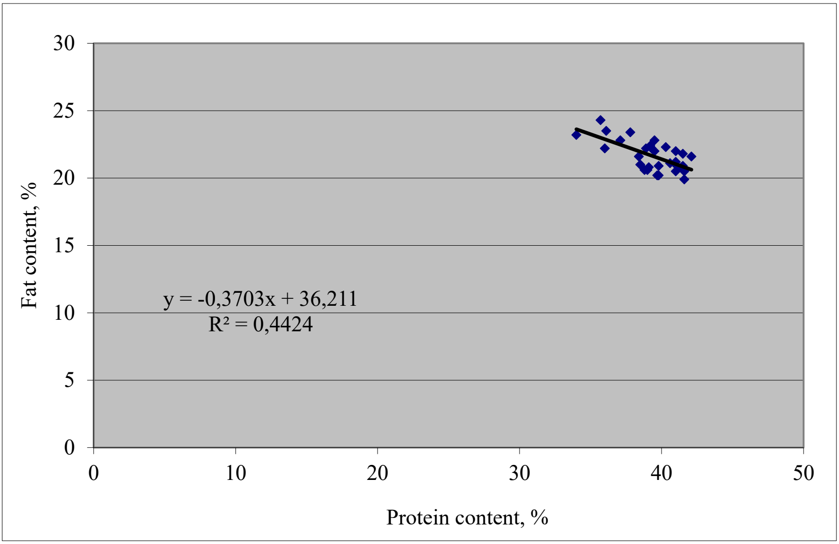

Figure 1. Correlation-regression dependence between protein (x) and fat (y) content in seeds of medium-ripe soybean varieties

An average negative correlation (r = – 0.535) was established between the seed yield of medium-ripe soybean varieties and the fat content, ie the higher the yield of medium-ripe soybean varieties, the lower the fat content in the seeds.

Along with the established correlation-regression dependences, some combinations of ecological factors were found in medium-ripe soybean varieties. In particular, the EU variety Pallador combined high yields with high attachment of lower beans, high plant height and the highest score of drought resistance and disease resistance; Amphora variety combines high yields with high resistance of plants to lodging and shedding of seeds; varieties Stein 11X02, Stein 14F06, Stein 17Zh32, Stein 15I63, Stein 13Zh23 combined high yields with the highest score of disease resistance. At the same time, the varieties Amphora and Stein 17G32 combined high yields and high protein content.

9. Conclusions and prospects for further research

After reviewing the scientific and experimental literature, it was determined that the main way to develop modern agriculture is not to increase the area of arable land, but to improve their use through intensive technologies. Therefore, it should be remembered that the variety is one of the main means of agricultural production, the genotype of which largely depends on the realization of the bioclimatic potential of the field, the effectiveness of agro-technological measures, especially in adverse environmental conditions. The biological potential of the field depends on the genetic characteristics of the variety, the ecological resources of a particular field and the technology of cultivation. Soybean varieties should be selected taking into account genetic and biological characteristics, in particular drought and cold resistance, especially in the early stages of development. The sensitivity of the variety to temperature and light regimes determines the duration of its growing season.

Thus, among the 31 medium-ripe soybean varieties included in the State Register of Plant Varieties Suitable for Growing in Ukraine in 2021, the highest yields were ES Pallador, Stein 14F06, Stein, Stein 15I63, Stein 13Zh23, Amphora. The highest protein content in the seeds was found in varieties Saidin, Amphora, Stein 17Zh32, Banjo KS, SG SR Picor, Stein 11X02, fat – Valentia, Vasilkovskaya, Tena, Apollo. The most drought-resistant varieties were Sandina, Panonka, ES Pallador.

Among the group of medium-late soybean varieties, the highest yield was Stein 20F26, the highest protein content in the seeds – Christina and Ananda, fat – Christina, the highest drought resistance was Svyatogor.

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