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TECHNOLOGICAL AND AGRO-ECOLOGICAL INDICATORS OF GROUPS OF SOYBEAN VARIETIES BY MATURITY

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У статті проаналізовано групи сортів сої за скоростиглістю за показниками екологічності, технологічності, стійкості до несприятливих умов вирощування, рівня врожайності та вмісту білка і жиру в насінні, що дозволить рекомендувати оптимальний структурний розподіл між сортами різних груп стиглості в Україні

Ключові слова: *соя, групи сортів, стиглість, врожайність, якість, технологічні показники, екологічні характеристики.*

Introduction. Soy, as a culture that can provide humanity with affordable vegetable protein for food, fodder for the livestock industry and raw materials for technical needs, is marked with a constant increase in its cultivated areas. The largest soybean-producing countries are the USA, Brazil and Argentina - grow it mainly on fertile soils with favorable moisture and heat conditions, in the so-called soybean belt [1]. Ukraine has a significant potential for increasing both the sown area and the yield of soybeans. Favorable regions for soybean cultivation in Ukraine are the Forest-Steppe zone, where about 60 % of all soybean acreage is concentrated, Polissia, where its acreage in the structure occupies 24 %, and the Steppe – 16 % of the acreage [2].

With the further aridity of the climate in Ukraine, with an increase in the sum of positive and active temperatures during the growing season, a decrease in the amount of precipitation, the spread of soil and air drought, the role of soybean varieties in maintaining its stable productivity and further increasing their productivity will significantly increase.

Analysis of recent researches and publications. In recent years in Ukraine the growth of sown areas and gross harvests of soybean seeds largely requires the introduction of new high-tech varieties adapted to specific soil and climatic conditions, with high resistance to adverse environmental factors, into agricultural production. Modern varieties of soybeans, in addition to high productivity, should be characterized with high protein and fat content, optimal duration of the growing season, resistance to diseases, pests and other adverse environmental factors, manufacturability during cultivation, and the ability to fix significant amounts of symbiotic nitrogen [3].

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 [4].

Modern soybean varieties should be characterized with high adaptive properties. Also, an important component of the variety composition of soybeans should be the quality of the harvest, ecological resistance to adverse environmental factors, and the economic feasibility of cultivation [5].

Choosing a soybean variety, it is necessary to take into account the natural and climatic conditions where it will be grown, the chemical composition of the seeds, and the height of the bottom beans. It is important that soybeans have at least 3 seeds and 10–11 productive nodes on the stem. The plant should be compact, with a finished type of growth. Also, a ripe and ready-to-harvest variety should not crack and crumble [6].

However, today there is a number of objective circumstances that do not allow to increase the productivity of soybeans at a rapid pace. Among them is the inconsistency of the varietal policy with the available assortment of soybean varieties of different maturity groups, which would be suitable for cultivation in the specific soil and climatic conditions of Ukraine.

Choosing a soybean variety, its important characteristic is the intensity of growth in the initial stages. Varieties which are characterized with high energy of initial growth quickly cover the surface of the soil and cause less evaporation of moisture from the soil. Also, an important characteristic of soybean varieties should be their high drought resistance, in particular, these should be varieties that are recommended for growing in the Steppe of Ukraine. It will make it possible to effectively store and use small reserves of moisture due to the reduction of evaporation and the complete coverage of the soil by the leaf apparatus, which will react more slowly to the moisture deficit [7].

In Ukraine, there is a fairly large assortment of soybeans of different maturity groups: ultra-early, early-ripening, medium-early-ripening, medium-ripening and medium-late-ripening. In the conditions of intensive agriculture with extreme weather conditions, it is important to grow several varieties of different groups of maturity in farms [8]. However, the determining factor in the structural distribution between these groups of varieties should be indicators of productivity, harvest quality, manufacturability and resistance to adverse conditions.

The purpose of the article is to analyze the groups of soybean varieties according to precociousness according to indicators of environmental friendliness, cultivation technology, resistance to adverse growing conditions, yield level, and the content of protein and fat in seeds, which will allow to recommend the optimal structural distribution between varieties of different groups of maturity in Ukraine.

The materials of research. The research was carried out by processing the State Register of plant varieties suitable for distribution in Ukraine for 2022. All groups of soybean varieties recommended for cultivation in Ukraine entered in the register were evaluated for maturity. Soybean varieties, in accordance with the state qualification examination, are evaluated for seed yield, resistance to diseases, adverse weather conditions, in particular drought, plant dormancy and seed shedding, to determine suitability for distribution in Ukraine. Resistance to damage by the most common soybean diseases was evaluated: downy mildew (*Peronospora manshurica* Sydow), ascochytosis (*Ascochytaso jaecola* Abramov), bacteriosis (*Pseudomonas*

savastonoipv. glycinea), septoria (*Septoria glycines* T. Hemmi), fusarium (*Fusarium* Link.).

The relative resistance of soybean varieties to disease, drought, plant dormancy and seed shedding is determined on a nine-point scale (1–9 points), according to which 9 points correspond to the highest resistance and 1 point to the lowest. The following gradation is used: 9 points – excellent stability; 7 points – persistence of goodness; 5 points – stability is satisfactory; 3 points – poor stability; 1 point – durability is very poor. The indicators with which the ecological assessment of soybean varieties was carried out are established in accordance with the Methodology for the examination of plant varieties of the cereal, cereal and leguminous groups for suitability for distribution in Ukraine. Experiments were conducted on plots of 10–25 m^2 in four repetitions.

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 bean in 25 plants. Resistance of soybean varieties to major diseases was determined by the percentage of affected plants, resistance to drought was determined based on visual assessment of plants during the growing season. A comparison of the studied indicators was carried out on the basis of mathematical and statistical correlational analysis.

The results of the research. Soybean varieties suitable for growing in Ukraine belong to five maturity groups: ultra-early – with a growing season of up to 85 days; early ripening – 86–105 days; medium early ripening – 106–125 days; medium ripe – 126–135 days and medium late ripe – 136–145 days. In total, 283 soybean varieties are listed in the State Register of Plant Varieties of Ukraine for 2022. Among the maturity groups of soybeans, the most numerous are mid-early ripening varieties, which make up 56 % of all varieties. The group of early-ripening varieties in the structure occupies 25 %, medium-ripening – 11 %, ultra-early – 6 %, and the varieties of the medium-late-ripening group are the least numerous – 2 % or only 4 varieties (Table 1).

Table 1. Assortment of soybean varieties by maturity groups in Ukraine

Ripeness group of varieties	Duration of the growing season, days	The number of varieties in the State Register of Ukraine, as of for 2021
Ultra-speed ripening	till 85	17
Early ripening	86–105	72
Medium-early ripening	106–125	159
Medium-ripening	126–135	31
Medium-late ripening	136–145	4

The main indicators of the manufacturability of soybean varieties are the height of the attachment of the lower beans, the height of the plants, the resistance of the plants to lodging and the resistance of the soybeans to seed shedding. The average height of attachment of lower beans of ultra-early, early-ripening and medium-early soybean varieties was the same and was 13 cm. In medium-ripening soybean varieties, the

average height of attachment of lower beans was 2 cm higher and amounted to 15 cm. The group of medium-late ripening had the highest average height of attachment of lower beans of soybean varieties, which was 4 cm higher than ultra-early, early-ripening and medium-early-ripening soybean varieties and amounted to 17 cm. It is the high placement of the lower beans from the soil surface that contributes to a more complete harvest with minimal losses, therefore it is the varieties of the medium-late-ripening group that have the height attachment of lower beans is the best for mechanized harvesting (Table 2).

Table 2. Indicators of manufacturability of maturity groups of soybean varieties in Ukraine

Group of varieties in ripeness	Duration of the growing season, days	The height of the attachment of the lower bean, cm	The height plant of, cm	Resistance to lying down, score	Resistance to shedding of seeds, score
Ultra-speed ripening	85	13	75	8,5	8,6
Early ripening	99	13	81	8,1	7,9
Medium-early ripening	115	13	81	8,2	8,1
Medium-ripening	129	15	85	8,2	8,3
Medium-late ripening	141	17	92	8,5	8,8

The lowest average plant height was ultra-early soybean varieties – 75 cm. Early and medium early-ripening soybean varieties were 6 cm taller than ultra-early and had an average height of 81 cm. Medium-ripening soybean varieties were 10 cm higher than ultra-early and had an average height of 85 cm. The highest were the varieties of the medium late ripening group – 92 cm, which were 17 cm higher than the ultra early ripening ones.

The highest average resistance to stem lodging was obtained by soybean varieties of the ultra-early and medium late ripening groups – 8.5 points each. If the high resistance to lodging of soybean plants of the ultra-early ripening group is ensured by the lowest plant height, compared to soybean varieties of other maturity groups, the varieties of the medium-late ripening group were the highest among all groups. In this group of varieties, the high resistance of plants to stem lodging is ensured by the high strength of the stem due to its large diameter, compared to the varieties of other maturity groups. The resistance to lodging of early-ripening, mid-early-ripening and mid-ripening soybean varieties was the same and amounted to 8.1–8.2 points. Varieties of these groups of ripeness in terms of height occupied an intermediate place between ultra-early and moderately late-ripened.

The varieties of the mid-late ripening group had the highest average resistance to seed shedding – 8.8 points and the ultra-early ripening group – 8.6 points. Early-ripening soybean varieties had the lowest average resistance to seed shedding – 7.9 points, and varieties of the medium-early and medium-ripening groups had average resistance to seed shedding – 8.1 and 8.3 points.

The indicators of agroecological stability of soybean varieties are their resistance to drought and diseases. The most drought-resistant were ultra-early varieties with an average resistance score of 8.4 and medium late-ripening varieties with a score of 8.3. If the varieties of the ultra-early ripening group have drought resistance provided by a short growing season and the formation of the crop before the drought, then the varieties of the medium-late ripening group – due to the formation of the crop in the late period, after the drought. At the same time, medium-ripening soybean varieties had the lowest drought resistance score – 7.9, and early-ripening and medium-early-ripening varieties – 8.0 points. Thus, the most resistant to drought were soybean varieties of the ultra-early and medium-late groups (Table 3).

Table 3. Indicators of agroecological sustainability, yield and seed quality of maturity groups of soybean varieties in Ukraine

Group of varieties in ripeness	Drought resistance, score	Disease resistance, score	Seed yield, t/ha	Protein content in seeds, %	Fat content in seeds, %
Ultra-speed ripening	8,4	8,8	2,34	40,7	21,0
Early ripening	8,0	8,5	2,59	40,1	21,2
Medium-early ripening	8,0	8,6	2,73	40,3	21,3
Medium ripening	7,9	8,6	2,52	39,4	21,6
Medium-late ripening	8,3	9,0	2,53	38,7	21,2

The average resistance to diseases in all groups of soybean varieties in terms of precocity was high. The most resistant to diseases were the varieties of the mid-late ripening group – 9.0 points. This is the highest score possible. Ultra-early varieties had an average disease resistance score of 8.8, medium-early and medium-ripening varieties had 8.6 points each, and early-ripening varieties had an average score of 8.5.

The determining indicator of all groups of soybean varieties according to maturity is their average yield. The highest productivity was established in varieties of the medium-early ripening group – 2.73 t/ha. Early ripening soybean varieties had a yield of 5.1 % less – 2.59 t/ha. Mid-late and mid-ripening soybean varieties had a yield of 7.3–7.7 % less than the yield of mid-early varieties and amounted to 2.53 and 2.52 t/ha, respectively. Soybean varieties of the ultra-early ripening group had the lowest average yield – 2.34 t/ha, which was 14.3 % less than the yield of the medium-early ripening group.

The highest average protein content in the seeds was obtained by varieties of the ultra-precocious group – 40.7 %. The protein content in the seeds was 0.4 % lower in the medium early ripening group – 40.3 %, in the early ripening group – 0.6 % lower – 40.1 %. The lowest average protein content in the seeds was found in varieties of the mid-late ripening and mid-ripening groups, 38.7 and 39.4 %, respectively, which was 2.0 and 1.3 % less than in the varieties of the ultra-early ripening group.

The average fat content in the seeds of soybean varieties of all maturity groups was approximately the same and amounted to 21.0–21.6 %. Varieties of the mid-ripe group had the highest average fat content, and ultra-early varieties had the lowest.

The analysis of the obtained indicators confirms that the medium-early ripening varieties of soybeans, which are characterized by the highest average seed yield, are the most numerous in terms of quantity. Medium-late soybean cultivars had the highest attachment height of lower beans, the highest plant height, the highest resistance scores to plant lodging, seed shedding, and disease, but had the lowest seed protein content. Mid-mature soybean cultivars had the highest seed fat content but the lowest drought tolerance score. Early maturing soybean varieties had the lowest resistance score to plant lodging, seed shedding and disease. Ultra-early soybean cultivars had the highest scores for lodging, drought tolerance, and the highest seed protein content, but had the lowest yield, lowest seed oil content, and lowest plant height.

The mathematical and statistical analysis of the obtained indicators established that a strong positive correlation r = 0.866 was established between the average duration of the growing season of soybean varieties of all maturity groups and the average height of attachment of the lower beans in them. That is, the longer the growing season of groups of soybean varieties, the higher the lower beans are attached from the soil surface in them (Table 4). A strong positive correlation r = 0.947 was established between the average duration of the growing season of groups of soybean varieties and their average plant height. That is, the longer the growing season of groups of soybean varieties, the greater their plant height.

A strong negative correlation r = – 0.923 was established between the average duration of the growing season of groups of soybean varieties and their average protein content in seeds. That is, the longer the growing season of groups of soybean varieties, the lower the protein content in their seeds. An average positive correlation of r = 0.607 was established between the average duration of the growing season of groups of soybean varieties and the average fat content in their seeds. That is, the longer the growing season of groups of soybean varieties, the higher the fat content in their seeds.

A strong positive correlation r = 0.920 was established between the average height of attachment of the lower beans of groups of soybean varieties and the average height of their plants. That is, the higher the height of the plants of groups of soybean varieties, the higher the lower beans are placed in them. A strong positive correlation r = 0.674 was established between the average attachment height of the lower beans of groups of soybean varieties and their average resistance to seed shedding. That is, the greater the height of attachment of the lower beans of plants of groups of soybean varieties, the greater their resistance to seed shedding.

Table 4. Correlation coefficients between studied factors of maturity groups of soybean varieties in Ukraine

Factor 1	Factor 2	Correlation coefficient, r
Duration of the growing season, days	The height of attachment of the lower beans, cm	0,866
Duration of the growing season, days	The height of plant, cm	0,947
Duration of the growing season, days	Protein content in seeds, %	- 0,923
Duration of the growing season, days	Fat content in seeds, %	0,607
The height of attachment of the lower beans, cm	Plant height, cm	0,920
The height of attachment of the lower beans, cm	Plant resistance to seed shedding, score	0,674
The height of attachment of the lower beans, cm	Resistance of plants to diseases, score	0,699
The height of attachment of the lower beans, cm	Protein content in seeds, %	- 0,959
The height of plant, cm	Protein content in seeds, %	- 0,981
Resistance of plants to lodging, score	Plant resistance to seed shedding, score	0,953
Resistance of plants to lodging, score	Drought resistance, score	0,925
Resistance of plants to lodging, score	Resistance of plants to diseases, score	0,935
Resistance of plants to lodging, score	Seed yield, t/ha	- 0,656
Plant resistance to seed shedding, score	Drought resistance, score	0,778
Plant resistance to seed shedding, score	Resistance of plants to diseases, score	0,960
Plant resistance to seed shedding, score	Seed yield, t/ha	- 0,602
Drought resistance, score	Resistance of plants to diseases, score	0,807
Drought resistance, score	Seed yield, t/ha	- 0,674
Drought resistance, score	Fat content in seeds, %	- 0,821

A strong positive correlation r = 0.699 was established between the average attachment height of the lower beans of groups of soybean varieties and their average resistance to diseases. That is, the higher the height of attachment of the lower beans of groups of soybean varieties, the greater their resistance to diseases. A strong negative correlation r = - 0.959 was established between the average attachment height of the lower beans of groups of soybean varieties and the average protein content in their seeds. That is, the higher the attachment height of the lower beans of groups of soybean varieties, the lower the protein content in the seeds.

A strong negative correlation r = - 0.981 was established between the average plant height of groups of soybean varieties and the average protein content in their seeds. That is, the higher the height of the plants of groups of soybean varieties, the lower their protein content. A strong positive correlation r = 0.953 was established between the average score of plant resistance to lodging of groups of soybean varieties and their average score of resistance to seed shedding. That is, the higher the resistance score of groups of soybean varieties to lodging, the higher their score of resistance to seed shedding.

A strong positive correlation r = 0.925 was established between the average score of plant resistance to lodging of groups of soybean varieties and their average score of drought resistance. That is, the higher the resistance score of groups of soybean varieties to lodging, the higher their drought resistance score. A strong positive correlation r = 0.935 was established between the average score of plant resistance to lodging of groups of soybean varieties and their average score of disease resistance. That is, the higher the resistance score of groups of soybean varieties to lodging, the higher their disease resistance score.

An average negative correlation r = -0.656 was established between the average score of plant resistance to lodging of groups of soybean varieties and their average seed yield. That is, the higher the resistance score of groups of soybean varieties to lodging, the lower their seed yield. A strong positive correlation r = 0.778 was established between the average score of plant resistance to seed shedding of groups of soybean varieties and their average score of drought resistance. That is, the higher the resistance score of groups of soybean varieties to seed shedding, the higher their drought resistance score.

A strong positive correlation r = 0.960 was established between the average score of plant resistance to seed shedding of groups of soybean varieties and their average score of disease resistance. That is, the higher the resistance score of groups of soybean varieties to seed shedding, the higher their disease resistance score. An average negative correlation r = - 0.602 was established between the average score of plant resistance to seed shedding of groups of soybean varieties and their average seed yield. That is, the higher the resistance score of groups of soybean varieties to seed shedding, the lower their yield.

A strong positive correlation r = 0.807 was established between the average score of drought resistance of plants of groups of soybean varieties and the average score of their resistance to diseases. That is, the greater the score of drought resistance of groups of soybean varieties, the greater their resistance to diseases. A strong negative correlation r = - 0.674 was established between the average score of drought resistance of plants of groups of soybean varieties and their average seed yield. That is, the greater the score of drought resistance of groups of soybean varieties then the lower it is.

Conclusions. Therefore, medium-early ripening soybean varieties are noted for the highest seed yield in Ukraine – 2.73 t/ha. It is the varieties of this group that should be the main ones in the structure of soybeans in Ukraine. The highest protein content in seeds is found in ultra-early varieties – 40.7 %, fat – in medium-ripening varieties – 21.6 %. Ultra-early and medium-late soybean varieties are characterized by the highest

resistance to plant lodging, seed shedding, drought and diseases. Therefore, ultra-early and medium-late varieties should complement medium-early varieties of soybeans. The share of early-ripening and medium-ripening ones should be the smallest.

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Annotation

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Technological and agroecological indicators of groups of soybean varieties by maturity

The prerequisites for the further increase in the productivity of soybean seeds in Ukraine under intensive farming and extreme weather conditions are the cultivation of several varieties of different maturity groups on farms. The indicators of productivity, harvest quality, manufacturability and resistance to adverse environmental conditions should be the determining factor in the structural distribution between groups of soybean varieties by maturity period.

The goal is to analyze the groups of soybean varieties according to precociousness according to indicators of environmental friendliness, cultivation technology, resistance to adverse growing conditions, yield level and protein and fat content in seeds, which will allow to recommend the optimal structural distribution between varieties of different groups of maturity in Ukraine. The research was carried out by processing the State Register of plant varieties which are suitable for distribution in Ukraine for 2022. All groups of soybean varieties are recommended for cultivation in Ukraine, included in the register, were evaluated for seed yield, resistance to diseases, adverse weather conditions, in particular drought, plant dormancy, and seed shedding.

Among the maturity groups of soybeans, the most numerous are mid-early ripening varieties, which make up 56 % of all varieties. The group of early-ripening varieties in the structure occupies 25 %, medium-ripening – 1 1%, ultra-early – 6 %, and varieties of the medium-late-ripening group are the least numerous – 2 % or only 4 varieties. The highest yield of seeds in Ukraine is noted for mid-early ripening soybean varieties – 2.73 t/ha. These are the varieties of this group that should be the main ones in the structure of soybeans in Ukraine. The highest protein content in seeds is found in ultra-early varieties – 40.7 %, fat – in medium-ripening varieties – 21.6 %. Ultra-early and medium-late soybean varieties are characterized with the highest resistance to plant lodging, seed shedding, drought and diseases. Therefore, ultra-early and medium-late varieties should complement medium-early varieties of soybeans. The share of early-ripening and medium-ripening ones should be the smallest.

Key words: *soybean, groups of varieties, ripeness, productivity, quality, technological indicators, ecological characteristics.*