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ECOLOGICAL ELASTICITY OF SOYBEAN VARIETIES' PERFORMANCE ACCORDING TO CLIMATIC FACTORS IN UKRAINE

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Abstract

This research aimed to determine the ecological elasticity of soybean varieties' performance of different maturity groups in the Sumy, Ternopil, and Mykolaiv regions. In the course of the research, 10 fast-growing, 6 early-ripening, 4 middle-early, and 3 mid-ripening varieties of domestic and foreign selection were used. The results of the analysis of the obtained data show that the formation of varieties' yield capacity is directly dependent on the length of the growing season, the amount of precipitation, and the temperatures. It was found that the highest level of yield capacity (2.75 t/ha on average) is formed by early-maturing soybean varieties, among which the Merlin variety is characterized by the highest yield - 3.08 t/ha.

***Key words**: soybean, varieties, maturity groups, yield capacity, ecological elasticity.*

INTRODUCTION

Creating varieties that can make the most efficient use of bioclimatic resources of a particular region, show tolerance to stressful environmental conditions, ensure the high realization of the genetic potential of performance, improvement of existing and development of new agrotechnical elements of cultivation technology is a strategic task of modern science (Datsko, 2017; Bakhmat et al., 2017).

Therefore, given the above, in terms of production, it is necessary to grow two or three varieties that differ in the length of the growing season, resistance to diseases, pests, and adverse environmental factors (temperature, drought, etc.), which is relevant in today's climate change (Bakal et al., 2017; Hornol et al., 2010; Skendži, 2021). Soybean varieties have a narrow ecological adaptation, so the technology of growing this crop should be based on the best, most adapted to the specific soil and climatic conditions of the zone of highly productive regionalized, and promising varieties (Mataa et al., 2019).

Varietal resources of soybeans in Ukraine consist of 80% of varieties of domestic selection and 20% of varieties of foreign selection, which gives a wide range of selection of varieties taking into account the growing area (Shevnikov et al., 2018).

Academician A.O. Babych points out that for each soil-climatic zone there is a group of varieties well adapted to the conditions of the regions. They ripen reliably and provide high yield capacity. At the same time, the author believes that the main areas under cultivation in the Forest-Steppe and Steppe should be occupied by middle-early and mid-ripening varieties that effectively use the entire growing season (Babich et al., 2010).

The introduction and distribution of varieties significantly depend on their biological characteristics and environmental conditions (Fichitsian et al., 2018). Therefore, each variety should be grown in the region or zone where there is the highest realization of the biological and genetic potential of performance (Langevish, 2017). Variety is one of the factors that significantly affect grain yield and quality (Fool, 2013; Dresselhaus et al., 2017). According to L. M. Sereda, the share of the variety in the formation of crop yields can be 30-35% (Wednesday, 2000). But such a high impact on the variety depends on the action of a set of conditions (level of soil fertility and moisture, biological potential of the variety, agricultural technology, etc.) (Kalenskaya et al., 2020).

The study aimed to determine the parameters of ecological plasticity and stability of soybean varieties of different origins, both domestic and Western European, based on the "yield capacity" of variable abiotic environmental factors and identify them by the yield level in different climatic conditions of Ukraine to help grain producers determine choosing varieties for their farms. This problem has become especially relevant in recent years, with a large variety of domestic and foreign varieties, which are often not adapted to certain conditions of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2017-2019 in the Sumy, Ternopil, and Mykolaiv regions, with different soils and climatic conditions.

23 soybean varieties of different maturity groups entered in the State Register of Plant Varieties Suitable for Distribution in Ukraine, of Ukrainian (fast-growing - Bilyavka, Mavka, Alians, Knyazhna, Samorodok, Khutoryanochka; early-ripening - Atlanta, Diadema Podillya; middle-early - Oriana, Vezha; mid-ripening - Vinni) and foreign (fast-growing - Kofu, Alaska, Tundra; early-ripening - Kyoto, Amadeus, Arisa, Merlin, Asuka; middle-early - Lissabon, Cordoba, mid-ripening - Padua, Kent) selections.

Soybean cultivation technology was recommended for the Left Bank Forest-Steppe zone. The predecessor is winter grain crops. Seed treatment with bacterial preparations was performed on the day of sowing. The sowing density is 650,000 similar seeds per hectare. The main fertilizer was applied in a spreading way: standard phosphate and potassium magnesia before plowing. Nitrogen fertilizers for pre-sowing cultivation were applied in the form of ammonium nitrate with the subsequent introduction into the soil. Sowing was carried out with a row spacing of 45 cm by MTZ 82.1 unit + Klen 1.5 C (breeding seeder). The depth of seed introduction is 4-5 cm. Experiment parameters are la = 3, lв = 8; n = 4, the accounting area is 30 m^2.

Coefficients of yield capacity elasticity (EA, E1, E2) of the crop by the sum of air temperature during the growing season and the number of precipitations were calculated by the formulas (Sich, 2005). The absolute coefficient of yield capacity elasticity (EA):

$$EA = \Delta y/\Delta x,$$

where: Δy is the range of yield capacity variability, t/ha; Δx is the range of variability of the factor between the same years as for yield. Relative coefficients of elasticity are of two types - E1 and E2:

$$E1 = \Delta y\ x\_av/100\Delta x,$$

Δy_x av is the average value between the two levels of the factor.

$$E2 = \Delta y\ x\_av/\Delta x\ y\_av,$$

where: Δx and Δy are the amplitude of variability of yield and factor, respectively; y_av and x_av are the average values of yield capacity and factor between the two levels.

RESULTS AND DISCUSSIONS

For a long time, the zone of the northeastern Forest-Steppe of Ukraine, which includes the Sumy region, was not part of the so-called "soy belt". But over the past 10 years, the area under this crop in the region has grown more than 10 times. Today, in terms of sown area, soybeans rank fourth in crop rotation after cereals, corn, and sunflower. The emergence of new high-yielding soybean varieties has allowed not only expanding the area of cultivation but also getting a high yield (Hlupak, 2013).

Yield capacity is the result of the complex interaction of plants by their genetic potential and a set of environmental factors. The soybean crop yield is a very multifaceted and complex property, which is about 26% due to the genotype of the variety. The formation of legumes' yield is characterized by high, differentiated action of numerous interrelated and interdependent factors, as well as the level of response to environmental conditions (Babych et al., 2000; Kaminsky, 2006).

The analysis of hydrothermal conditions and yield capacity indicators shows that the moisture supply and temperature regime of the soybean growing season were different over the years and had a significant impact on the level of seed yield capacity.

In terms of weather conditions, the years differed significantly. According to the data obtained, the most favorable conditions for the formation of soybean yield capacity developed in 2018 and 2019, while in 2017 they were the most unfavorable (environmental conditions index was -0.47 for the Sumy region, -0.37 for the Ternopil region, and 0.41 for the Mykolaiv region) to obtain high yields of the studied culture. Meteorological conditions of the soybean growing season in 2017 were characterized by periodic decrease, and in some decades, on the contrary, an increase in air temperature and uneven distribution of precipitation in critical periods of growth and development of soybean plants, which led to low seed yield capacity due to low plant abortion of flowers and ovaries. The highest level of yield capacity was formed by the early-ripening variety of Merlin, and the lowest - by the early-ripening variety of Vezha (Table 1).

Table 1. Seed yield of soybean varieties of different maturity groups grown in Sumy, Ternopil, and Mykolaiv regions on average for 2017-2019, t/ha

Maturity group	Variety	Sumy region	Ternopil region	Mykolaiv region	Average
Fast-growing	Asuka	2.81	3.26	2.48	2.85
	Kofu	2.30	3.50	2.37	2.72
	Alaska	2.43	3.00	2.34	2.59
	Khutoryanochka	2.11	2.78	2.30	2.40
	Knyazha	2.10	2.61	2.23	2.31
	Samorodok	2.27	2.64	2.24	2.38
	Tundra	2.65	3.01	2.34	2.67
	Bilyavka	1.89	2.80	2.21	2.30
	Mavka	2.38	2.61	2.16	2.38
	Alians	2.32	2.65	2.34	2.44
Early-ripening	Kioto	2.89	3.44	2.78	2.04
	Amadeus	2.43	3.14	2.55	2.71
	Arisa	2.66	2.85	2.44	2.65
	Merlin	3.06	3.31	2.88	3.08
	Diadema Podillya	2.64	2.99	2.48	2.70
	Atlanta	2.27	2.46	2.31	2.35
Middle-early	Lissabon	2.85	2.68	2.46	2.66
	Kordoba	2.61	3.20	2.53	2.78
	Oriana	2.58	2.53	2.03	2.38
	Vezha	1.89	2.55	2.20	1.21
Mid-ripening	Kent	2.72	3.25	2.85	2.94
	Padua	1.92	2.82	2.43	1.39
	Vinni	2.37	2.83	2.19	2.46
Average		**2.44**	**2.91**	**2.40**	**2.58**
Duncan test $_{05}$ (for the groups of varieties)		**0.28**	**0.25**	**0.28**	

The results of the research conducted during 2017-2019 show the seed yield of soybean varieties to range from 1.21 to 3.08 t/ha, with an average yield capacity of 2.58 t/ha of varieties. Significantly higher than average yield capacity was shown by fast-growing varieties of Asuka, Kofu, Alaska, and Tundra (2.85, 2.72, 2.59, and 2.67 t/ha, respectively); early-ripening - Amadeus, Arisa, and Diadema Podillya (respectively 2.71, 2.65, and 2.70 t/ha); middle-early - Lissabon (2.66 t/ha) and Kordoba (2.78 t/ha); mid-ripening - Kent (2.94 t/ha). On the contrary, the yield capacity of such fast-ripening varieties as Bilyavka, Knyazha, Khutoryanochka, Samorodok, Mavka, and Alians was low (respectively, 2.30, 2.31, 2.40, 2.38, 2.38, and 2.44 t/ha); early-ripening - Atlanta (2.35 t/ha) and Kioto (2.04 t/ha); middle-early - Vezha (1.21 t/ha), Oriana (2.38 t/ha), and mid-ripening - Padua (1.39 t/ha) and Vinni (2.46 t/ha).

Asuka turned out to be more productive of the fast-growing varieties - 2.85 t/ha, whereas Bilyavka had lower performance averaged 2.30 t/ha over the years of research. The average yield capacity in this group was 2.50 t/ha.

Studies have shown that the longer the growing season the plants had, the higher their yield capacity was.

In terms of performance, a group of early-maturing varieties took first place. Its average yield was 2.75 t/ha. In this group, the highest level of adaptability was shown by Merlin variety, which during 2017-2019 formed the highest level of yield capacity - 3.08 t/ha under the same growing conditions as other varieties. The lowest yield of the studied early-ripening soybean varieties was Kioto - 2.04 t/ha.

The second place in terms of soybean seed performance was occupied by a group of middle-early varieties with an average yield capacity of 2.48 t/ha.

Concerning the varieties of the middle-early group, it is worth noting that the variety of Kordoba was more productive with a seed yield of 2.78 t/ha. The variety of Vezha had the lowest yield - 1.21 t/ha.

Having analyzed the group of medium-ripe varieties, we can conclude that in the region, Padua soybean variety had a yield capacity of 1.39 t/ha, the Vinni variety - of 2.46 t/ha. The highest yield was formed in the variety of Kent - 2.94 t/ha. The average yield capacity in this group was 2.6 t/ha.

The results of the analysis of the yield capacity of varieties of different maturity groups among the regions show that the most promising region for soybean cultivation is Ternopil, where the average yield was 2.91 t/ha. The Mykolaiv region is characterized by the lowest average yield capacity of grades - 2.40 t/ha.

Thus, the most promising varieties for growing in the Sumy region are: among the group of fast-growing varieties - Asuka and Tundra; among the group of early-ripening soybean varieties - Merlin and Kioto; among the group of middle-early varieties - Lissabon and Kordoba; among the group of mid-ripening varieties - Kent and Vinni.

It has been experimentally established that to obtain highly productive soybean agrobiocenoses in the western part of the Forest-Steppe of Ukraine, it is necessary to take a balanced approach to the choice of soybean varieties of different maturity groups. The level of yield capacity formation of soybean varieties determines such an indicator as the early maturity of the variety. For the conditions of the western Forest-Steppe zone, the cultivation of early-ripening (Kioto, Merlin, and Amadeus) and mid-ripening (Kent, Vinni, and Padua) soybean varieties are effective.

Analysis of the research results showed that the average yield of soybean varieties of fast-growing and middle-early groups for cultivation in the southern steppe of Ukraine was relatively high - 2.30 t/ha. As a result of determining the yield capacity on average over three years of study, the best varieties of soybeans of the fast-growing group were identified, which provided high yield capacity: Asuka (2.48 t/ha), Kofu (2.37 t/ha), Alaska, Tundra, and Alians (2.34 t/ha each).

For the stable production of soybean seeds in the Sumy region, which is characterized by high weather variability, diversity of soil, and climatic zones, it is advisable to choose three or four different fast-growing varieties, differing in length of the growing season, resistance to diseases, pests, and adverse environmental factors (low temperatures, droughts, etc.).

Analyzing yield capacity and stability of a variety or agronomic techniques, it is important to simultaneously assess the response to changes in environmental factors. The key factor is the temperature and moisture regime during the growing season. The expediency of using three coefficients of yield capacity elasticity (EA, E1, E2) of crops on the sum of air temperature for vegetation and the sum of precipitation is calculated and proved. Absolute yield capacity elasticity (EA): characterizes how many units increase (or decrease) the yield capacity with a corresponding increase (or decrease) of the factor per unit. If it has a sign "-", then the resulting pattern is reversed (an increase in yield capacity due to a decrease in the value of the active factor (or vice versa)). The disadvantage of this factor is the inability to use it to compare different crops and traits with each other.

Relative coefficients of elasticity are of two types - E1 and E2. The first one characterizes the change in yield capacity in t/ha by 1% change in the factor relative to its average. In the range from *xmin* to *xmax* this coefficient is not the same. Therefore, it is determined for the middle level. The second coefficient of elasticity (E2) is the most universal and allows comparing different crops or varieties depending on changes in different factors. It takes the value "+" or "-" and characterizes the change of 1% yield capacity when the factor changes by 1%. The universality of this coefficient is that it allows comparing different crops and varieties, regardless of the studied factor.

Thus, for the conditions of the Sumy region among soybean varieties, early-ripening ones react the most to changes in temperature. Thus, in the variety of Diadema Podillya, an increase in temperature by 1 ° C increased the yield capacity by 7 kg/ha (EA = 0.007). Amadeus variety was more sensitive to changes in temperature, as evidenced by a sharp increase in EA (EA = 0.010) (Table 2). It should be noted that the early-ripening variety of Kioto received an inverse pattern - the decrease in yield capacity is due to an increase in the sum of temperatures during the growing season (EA = -0.016). Varieties of the fast-growing group reacted to changes in temperature also differently. Precocious variety Asuka and Alians responded positively to the increase in temperatures during the growing season (EA = 0.006). The rest of the varieties of this group increased the yield by 3-5 kg/ha (EA = 0.003 ÷ 0.005). In middle-early soybean varieties, the yield increased by an average of 5.25 kg/ha with increasing temperature by 1°C (EA = 0.003 ÷ 0.007).

Table 2. Coefficients of yield capacity elasticity of soybean varieties depending on climatic factors in the Sumy region, the average for 2017-2019

Variety	Yield capacity, t/ha	Coefficients of elasticity by air temperature (°C) and precipitation (mm) during the growing season							
		Temperatures, °C				Precipitation, mm			
	R (Δy)	Δx	E_A	E_1	E_2	Δx	E_A	E_1	E_2
Kioto	0.59	-35.9	-0.016	-0.40	-13.77	94.2	0.006	0.01	0.30
Amadeus	1.39	139.7	0.010	0.24	9.91	32.5	0.043	0.06	2.47
Arisa	0.28	139.7	0.002	0.05	1.82	32.5	0.009	0.01	0.45
Merlin	0.53	175.6	0.003	0.07	2.39	-61.7	-0.009	-0.01	-0.39
Diadema Podillya	0.93	139.7	0.007	0.16	6.11	-61.7	-0.015	-0.02	-0.80
Atlanta	0.97	175.6	0.006	0.13	5.89	-61.7	-0.016	-0.02	-0.97
Asuka	0.59	168.3	0.004	0.07	2.61	32.8	0.018	0.02	0.87
Kofu	0.96	168.3	0.006	0.12	5.19	32.8	0.029	0.04	1.74
Alaska	0.97	191.0	0.005	0.11	4.37	-62.3	-0.016	-0.02	-0.87
Khutoryanochka	0.51	168.3	0.003	0.06	3.00	32.8	0.016	0.02	1.00
Knyazha	0.81	168.3	0.005	0.10	4.79	-62.3	-0.013	-0.02	-0.84
Samorodok	0.84	191.0	0.004	0.09	4.05	32.8	0.026	0.03	1.54
Tundra	0.53	191.0	0.003	0.06	2.19	-62.3	-0.009	-0.01	-0.44
Bilyavka	0.70	191.0	0.004	0.08	4.06	-62.3	-0.011	-0.02	-0.81
Mavka	0.96	191.0	0.005	0.11	4.42	-62.3	-0.015	-0.02	-0.88
Alians	1.11	191.0	0.006	0.12	5.24	-62.3	-0.018	-0.02	-1.05
Lissabon	1.06	148.5	0.007	0.16	5.55	32.8	0.032	0.04	1.55
Kordoba	0.73	148.5	0.005	0.11	4.17	32.8	0.022	0.03	1.16
Oriana	1.09	172.0	0.006	0.14	5.44	-62.3	-0.017	-0.02	-0.92
Vezha	0.52	172.0	0.003	0.07	3.54	-62.3	-0.008	-0.01	-0.60
Kent	0.61	187.6	0.003	0.08	3.01	26.3	0.023	0.03	1.21
Padua	0.70	187.6	0.004	0.09	4.89	26.3	0.027	0.04	1.97
Vinni	0.88	210.8	0.004	0.11	4.43	-67.9	-0.013	-0.02	-0.78

Note: The temperature and humidity regimes correspond to the conditions of the year in which the maximum (ymax) and minimum (ymin) yields were obtained.

Comparing the relative coefficients of elasticity (E2), soybean varieties in response to changes in temperature can be placed in the following order: fast-growing (E2 = 3.99 on average per group) – mid-ripening (E2 = 4.11) – middle-early (E2 = 4.68) – early-ripening (E2 = 5.22). That is, an increase in the sum of temperatures by 1% leads to an increase in yield capacity by 1.82-9.91% depending on the variety. The exception was Kioto variety, in which a 1% increase in temperature resulted in a 13.77% decrease in yield.

It should be noted that with an increase in precipitation by 1 mm, the yield capacity decreases by 9.0 kg/ha in the varieties of Merlin and Tundra; 13.0 ku in the varieties of Vinni and Khutoryanochka; 15.0 kg/ha in the varieties of Diadema Podillya and Mavka; 16.0 kg/ha in the varieties of Alaska and Atlanta; 17.0 kg/ha in Oriana variety; 18.0 kg/ha in the variety of Alliance. In the varieties of Kioto and Arisa, an increase in precipitation by 1 mm contributed to an increase in yield capacity of 6.0 and 9.0 kg/ha. The maximum value of the coefficient of elasticity was observed in the variety of Amadeus (EA = 0.043).

In other varieties, an increase in the amount of precipitation led to an increase in yield capacity by 0.018-0.032 t/ha or 18.0-32.0 kg/ha. Besides, the coefficient of elasticity indicates what percent of the effective trait (yield capacity) will increase with an increase in precipitation by 1%. The higher coefficient of elasticity (E2) was 2.47 in the Amadeus variety and 1.97 in the Padua variety. In the Kofu variety, this figure was 1.74%.

A comparative analysis of the effect of different amounts of precipitation on the formation of soybean yield capacity showed that 1% increase in precipitation contributed to a decrease in soybean yield by 1.05% in the variety of Alians, 0.97% - in the variety of Atlanta, 0.92% - in the variety of Oriana. The lowest figure was -0.39% in the Merlin variety.

Thus, the formation of soybean yield capacity is directly dependent on the total of temperatures and precipitation. The increase in soybean seed yield capacity from an increase in precipitation by 1 mm is from 6.0 to 43.0 kg/ha. Under conditions of increasing temperatures by 1°C, the yield capacity of soybean seeds increases by 2.0-10.0 kg/ha (Table 3).

Table 3. Coefficients of yield capacity elasticity of soybean varieties depending on climatic factors in the Ternopil region, the average for 2017-2019

Variety	Yield capacity, t/ha	Coefficients of elasticity by air temperature (°C) and precipitation (mm) during the growing season							
		Temperatures, °C				Precipitation, mm			
	R (Δy)	Δx	E_A	E_1	E_2	Δx	E_A	E_1	E_2
Kioto	0.86	0.9	1.000	21.0	610.5	-57.2	-0.015	0.0	-1.3
Amadeus	0.88	0.9	1.000	21.0	668.8	-57.2	-0.015	-0.2	-1.5
Arisa	1.25	1.3	1.000	21.0	738.5	-57.2	-0.022	-0.1	-2.3
Merlin	1.11	63.8	0.017	0.4	11.0	-57.2	-0.019	-0.2	-1.7
Diadema Podillya	0.97	63.8	0.015	0.3	10.7	-57.2	-0.017	-0.2	-1.7
Atlanta	0.80	63.8	0.013	0.3	10.7	-57.2	-0.014	-0.1	-1.7
Asuka	0.71	143.5	0.005	0.1	2.8	-101.4	-0.007	-0.1	-0.6
Kofu	0.71	-6.5	-0.109	-2.0	-56.8	20.0	0.036	0.5	2.7
Alaska	0.33	-6.5	-0.051	-0.9	-30.8	20.0	0.017	0.4	1.4
Khutoryanochka	0.57	-6.5	-0.088	-1.6	-57.4	20.0	0.029	0.4	2.7
Knyazha	0.83	-6.5	-0.128	-2.3	-89.0	20.0	0.042	0.3	4.2
Samorodok	0.65	-6.5	-0.100	-1.8	-69.0	20.0	0.033	0.3	3.2
Tundra	0.68	-6.5	-0.105	-1.9	-63.2	20.0	0.034	0.4	3.0
Bilyavka	0.78	-6.5	-0.120	-2.2	-78.0	20.0	0.039	0.4	3.7
Mavka	0.78	-6.5	-0.120	-2.2	-83.5	20.0	0.039	0.3	3.9
Alians	0.71	-6.5	-0.109	-2.0	-75.1	20.0	0.036	0.3	3.5
Lissabon	0.84	23.0	0.037	0.7	26.0	-14.0	-0.060	-0.5	-6.2
Kordoba	0.68	23.0	0.030	0.6	17.6	-14.0	-0.049	-0.6	-4.2
Oriana	0.76	23.0	0.033	0.6	24.9	-14.0	-0.054	-0.5	-6.0
Vezha	0.91	23.0	0.040	0.8	29.6	-14.0	-0.065	-0.5	-7.1
Kent	0.65	162.9	0.004	0.1	2.7	-116.8	-0.006	-0.1	-0.5
Padua	0.86	87.5	0.010	0.2	7.6	-63.7	-0.014	-0.1	-1.5
Vinni	0.79	87.5	0.009	0.2	7.0	-63.7	-0.012	-0.1	-1.3

Note: The temperature and humidity regimes correspond to the conditions of the year in which the maximum (ymax) and minimum (ymin) yields were obtained.

The analysis of the results of elasticity coefficients in the Ternopil region showed that early-maturing soybean varieties are most responsive to changes in temperature. Thus, if in the early-ripening variety of Kent and the mid-ripening variety of Asuka the increase in temperature by 1°C led to an increase in the yield capacity by 4 and 5 kg/ha (EA = 0.004 and EA = 0.005), in the early-ripening varieties of Atlanta, Diadema Podillya, and Merlin, the coefficient of elasticity was 0.013, 0.015, and 0.017. Slightly higher rates were for growing middle-early varieties of Kordoba (EA = 0.030), Oriana (EA = 0.033), and Vezha (EA = 0.040). Early-ripening varieties of Kioto, Amadeus, and Arisa were more sensitive to changes in temperature, as evidenced by a sharp increase in EA (EA = 1.00) (Table 3). During the cultivation of fast-growing soybean varieties, the inverse pattern was obtained - the decrease in yield is due to the increase in temperatures during the growing season (EA = -0.051 ÷ -0.128). Analyzing the relative coefficients of elasticity (E2), it is worth noting that the increase in temperature by 1% contributed to the increase in yield capacity of early-ripening groups by 10.7-738.5%, middle-early group by 17.6-29.6%, mid-ripening group - by 2.7-7.6%. When cultivating fast-growing soybean varieties, the relative coefficient of elasticity (E2) was negative and amounted to -30.8 ÷ -89.0%. That is, reducing temperatures by 1% leads to increased yield capacity.

It has been established that with a decrease in the amount of precipitation by 1 mm, the yield capacity increases by 14.0-22.0 kg/ha in early-ripening varieties; 49.0-65.0 kg in middle-early varieties; 6.0-14.0 kg/ha in mid-ripening soybean varieties. During the cultivation of fast-growing soybean varieties, an increase in precipitation by 1 mm contributed to an increase in yield capacity of 14.0 and 42.0 kg/ha. In other words, the increase in precipitation by 1% contributed to the increase in yield capacity by 1.4-4.2%.

Thus, the regularity of the influence of weather conditions on the yield capacity of soybean varieties can be traced. The yield capacity of the plant depends on temperatures during the growing season. With an increase in the sum of temperatures by 1%, the yield capacity increases in early-ripening, middle-early and mid-ripening varieties by 2.7 ÷ 738.5%, and in fast-growing varieties on the contrary - with the increase in temperature yield capacity decreases by -57.4 ÷ -89.0%. Yield capacity is affected by the amount of precipitation. The analysis showed the inverse dependence of soybean yield capacity on the amount of precipitation during the growing season, an increase in the amount of precipitation for the growing season by 1% leads to yield capacity decrease by -0.5 ÷ -7.1%, and for cultivating fast-growing varieties - increased precipitation contributed to increased yield capacity by 1.4 ÷ 4.2%.

According to the coefficient of elasticity (E2) in terms of the Mykolaiv region, it has been determined by what percent the effective sign of yield capacity (У) of soybean seeds will increase with the increase in the amount of precipitation (R, mm) and temperatures (T, °C) by 1%. In terms of the Mykolaiv area, the increase in soybean yield capacity at 1% increase in the amount of precipitation for vegetation is noted for the cultivation of early-ripening, middle-early and mid-ripening varieties (Table 4).

The highest coefficient of elasticity with 1% increase in the amount of precipitation was observed for the cultivation of mid-ripening varieties of Padua - 12.4% and Kent - 8.9%; early-ripening - Merlin and Kioto (E2 = 6.5%). During the cultivation of fast-growing soybean varieties, an increase in the amount of precipitation by 1% contributed to a decrease in seed yield capacity by E2 = -4.7 ÷ -8.5%. Mavka had the highest results.

Thus, the high yield capacity of soybean seeds is more pronounced with a high amount of precipitation.

When analyzing the dependence of changes in soybean seed yield capacity on temperatures, it was found to decrease by 8.2-175.7% in terms of increasing the sum of temperatures by 1%. Only during the cultivation of the Bilyavka variety, the yield capacity increase by 27.8% with an increase in temperatures by 1%.

Thus, the results of the influence of temperature and precipitation on soybean yield capacity by the elasticity coefficient showed that the formation of yield is directly dependent on the amount of precipitation and temperatures. The increase in yield capacity in terms of the increase in precipitation by 1 mm is from 5 to 203 kg/ha. In terms of increasing temperatures by 1°C, soybean yield capacity decreases by 1.0-15.0 kg/ha.

Table 4. Coefficients of yield capacity elasticity of soybean varieties depending on climatic factors in the Mykolaiv region, the average for 2017-2019

Variety	Yield capacity, t/ha	Coefficients of elasticity by air temperature (°C) and precipitation (mm) during the growing season							
		Temperatures, °C				Precipitation, mm			
	R (Δy)	Δx	E_A	E_1	E_2	Δx	E_A	E_1	E_2
Kioto	0.96	-48.3	-0.02	-0.5	-17.7	7.8	0.123	0.2	6.5
Amadeus	0.76	-48.3	-0.02	-0.4	-15.2	7.8	0.097	0.5	5.6
Arisa	0.65	-48.3	-0.01	-0.3	-13.6	7.8	0.083	0.5	5.0
Merlin	0.99	-48.3	-0.02	-0.5	-17.6	7.8	0.127	0.5	6.5
Diadema Podillya	0.63	-48.3	-0.01	-0.3	-13.0	7.8	0.081	0.5	4.8
Atlanta	0.47	-48.3	-0.01	-0.2	-10.4	7.8	0.060	0.4	3.8
Asuka	0.65	-44.0	-0.01	-0.3	-12.6	-5.1	-0.127	-0.5	-5.5
Kofu	0.58	-44.0	-0.01	-0.3	-11.7	-5.1	-0.114	-0.5	-5.1
Alaska	0.66	-44.0	-0.02	-0.3	-13.5	-5.1	-0.129	-0.5	-5.9
Khutoryanochka	0.67	-44.0	-0.02	-0.3	-14.0	-5.1	-0.131	-0.5	-6.1
Knyazha	0.68	-44.0	-0.02	-0.3	-14.6	-5.1	-0.133	-0.5	-6.4
Samorodok	0.51	-44.0	-0.01	-0.2	-10.9	-5.1	-0.100	-0.5	-4.8
Tundra	0.55	-44.0	-0.01	-0.3	-11.3	-5.1	-0.108	-0.5	-4.9
Bilyavka	0.88	30.2	0.03	0.6	27.8	94	0.009	0.03	0.5
Mavka	0.88	-44.0	-0.02	-0.4	-19.5	-5.1	-0.173	-0.5	-8.5
Alians	0.52	-44.0	-0.01	-0.2	-10.7	-5.1	-0.102	-0.5	-4.7
Lissabon	0.68	-66.7	-0.01	-0.2	-9.2	13.8	0.049	0.2	2.6
Kordoba	1.07	-66.7	-0.02	-0.4	-14.1	13.8	0.078	0.2	4.0
Oriana	0.67	-9.1	-0.07	-1.6	-80.9	99.3	0.007	0.0	0.4
Vezha	0.54	-66.7	-0.01	-0.2	-8.2	13.8	0.039	0.2	2.3
Kent	0.65	-36.2	-0.02	-0.5	-16.3	3.8	0.171	1.1	8.9
Padua	0.77	-36.2	-0.02	-0.5	-22.6	3.8	0.203	1.0	12.4
Vinni	0.64	-4.3	-0.15	-3.8	-175.7	135.3	0.005	0.02	0.3

Note: The temperature and humidity regimes correspond to the conditions of the year in which the maximum (ymax) and minimum (ymin) yields were obtained.

CONCLUSIONS

Ukraine has the largest gene pool and soybean varietal composition in Europe. Soybean varieties were created mainly by classical selection methods, without genetic modifications, in terms of seed yield capacity (3.0-4.9 t/ha) and protein content (39-43%), they are not inferior to the best foreign varieties, and in some respects exceed them. Nevertheless, many aspects of improving economically valuable traits through selection have not yet been resolved. First, it concerns the issue of increasing the adaptive potential of the crop. In recent years, there has been not only an increase in air temperature in the spring and summer seasons with a long rainy period but also the combined effect of these factors in a short time. Therefore, new generation soybean varieties, as well as agrocenoses created on their basis, should have high-performance potential, greater sensitivity to varietal cultivation technology, form high performance and seed quality, be less dependent on unregulated environmental factors, stressful situations, which are manifested during the growing season. The correct choice of the maturity group of culture is a necessary condition for the efficient use of environmental resources for the formation of high yields. On each farm, you need to grow two or three varieties that differ in the length of the growing season.

Weather conditions of the soybean growing season in all regions corresponded to the trends of recent years, i.e., a decrease in precipitation and an increase in air temperature. The most comfortable weather conditions for the growth and development of soybean plants developed in 2018, and unfavorable ones were in 2017.

In the Sumy region, cultivating soybeans, preference should be given to varieties of early and middle-early maturity; and in the Ternopil region – to fast-growing and middle-ripening groups. In the Mykolaiv region, the main areas of soybeans should be occupied by early-ripening and mid-ripening varieties, which use the vegetative period more effectively and form a bigger yield.

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