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Varietal features of elements of soybean cultivation technology during irrigation

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Abstract. An important advantage of soybean (*Glycine max* (L.) Merr.) over other crops is a prominent protein content and a balanced amino acid composition, in connection with which the creation of a wide range of varieties becomes relevant, as their cultivation could meet the needs of processing industries, as well as the development of optimal varietal cultivation technologies, which allow unleashing the genotypic potential of productivity. The purpose of this study was to substantiate the specific features of the formation of productivity of modern soybean varieties depending on the elements of cultivation technology in irrigation conditions. Research methods: field, morphometric,

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laboratory, statistical (correlation and regression analysis). Field studies were conducted during 2019-2021 in the agroecological zone of the Southern Steppe within the Kakhovka Irrigation System. Features of the growth and development of soybean varieties of different maturity groups were established: fast crops – Monarkh, Arnika, early crops – Pysanka, Sofia, mid-early – Sviatohor, Evridika. The yield of soybean varieties varied depending on the timing of sowing, plant density, and varietal characteristics. The maximum productivity of crops of early varieties Arnika and Monarkh at 2.81-3.39 t/ha was formed during the sowing period of May 1 and the optimal sowing density of 700 thous. plants/ha. In the group of early crops, Sofiia and Pysanka varieties showed the maximum yield of 3.17-3.22 t/ha during the sowing period of May 1 and plant density of 700 thous. plants/ha. Varieties of the mid-early crops Sviatohor, Evridika gave the maximum yield of 3.76-4.28 t/ha for sowing on May 1 and a density of 500 thous. plants/ha. To obtain the maximum yield of soybeans under irrigation conditions, there is an optimal sowing period and an optimal density of coenosis for each maturity group of varieties: fast crops showed the maximum yield when sowing on May 1 and with a density of 700 thous. plants/ha, early and mid-early crops – when sowing on May 1 and with a plant density of 500 thous. plants/ha. The results of this study can be used in production conditions to adjust the elements of agricultural technology of soybean seed production and obtain high yields with a prominent level of profitability

Keywords: sowing period; plant density; yield; dry matter weight; thousand kernel weight

INTRODUCTION

Soybeans have the potential to increase the sustainability of agricultural production systems, and therefore more attention is needed to spread this crop, specifically in the EU. A more profound understanding of the key determinants that affect soybean germination and rooting is the first step to facilitate its implementation in agricultural systems.

The yield of soybean grain is determined by the interaction of the plant, the external environment and the growing technology. In agrotechnical activities, research focuses on crop density and row spacing. Hlupak (2020) found that increasing the density of coenosis to certain parameters of plant density leads to an increase in yield, but a further increase in the density of coenosis causes shading of plants and a decrease in the yield of individual varieties of different genotypic origin.

Furman *et al.* (2022) established that in thinned crops, plants branch intensively, form an excessive number of leaves, beans, and seeds, under the weight of which and under the influence of wind gusts, the branches often break off. Beans in such crops are attached low on the stem and ripen unevenly, which leads to a decrease in the overall yield, despite the usually high individual productivity of the crops.

Research conducted in Sichuan Province (China) established that it is possible to achieve the maximum accumulation of biomass and its redistribution in favour of beans and grain during the soybean sowing period, specifically, the early periods contribute to a greater development of biomass and productivity (Ahmed *et al.*, 2018). In the climatic conditions of Korea, it was found that the density of soybean crops can regulate the morphometric characteristics of plants and promote more efficient use of light energy, which can improve the photosynthesis and increase yield (Lee *et al.,* 2019).

Jańczak-Pieniążek *et al.* (2021) noted that the corresponding variety of soybean crop density is the main intangible and environmental factor of agricultural technology. Studies in Poland proved that the yield was more affected by weather conditions. Strong plant density reduced the parameters of the productivity structure, increased the height of plants.

Lamichhane *et al.* (2020) carried out field studies for three sowing periods from mid-March to mid-April in the northern climatic zone of France to estimate the possibility of expanding soybean areas in the northern part of the country in the future due to climate changes. Their study indicated that the main reasons for the decrease in field germination included soil crust, low-temperature soil, drying of the upper soil layer. These results necessitate the creation of soybean varieties with increased cold resistance for early sowing periods.

Markovska *et al.* (2023) found that a large amount of precipitation, a cold, prolonged spring, high humidity and low soil temperature lead to the lengthening of individual phenological phases of soybean plant development, the occurrence of stressful conditions and, as a result, a general weakening of soybean plants and pathogen damage.

Didora *et al.* (2022) in the conditions of Polissia and Milenko *et al.* (2022) in the conditions of the Poltava region, established the response of fast-growing soybean varieties to improved elements of cultivation technology under conditions of natural moisture availability. Varietal responses were established for each region, the best genotypes and improved technology elements were recommended, which indicates the need to improve varietal technology in each agroecological zone. The early sowing period (at 10-15°C) led to a delay in germination and seedling. Early sowing resulted in more nodes, but shorter internodes. The delay in sowing after May 1 led to a significant linear decrease in seed yield, which indicates the importance of early

sowing for unleashing the yield potential of the variety and efficient use of moisture.

Rybalchenko (2018) proved that one of the crucial elements of soybean plant productivity that affects the formation of real yield is the thousand kernel weight. The parameters of this indicator are controlled by the genotype of the variety, as well as technological methods of cultivation.

Fellahi *et al*. (2020) indicate that grain size is an important feature that determines the yield of a variety for grain crops. Therewith, selections based on a set of attributes calculated using index ratios provide a more reliable assessment. Bizari *et al*. (2017) found that index scores for multiple traits when evaluating the productivity of soybean varieties were more informative than estimates for individual traits and yields. For the genotypic characteristics of grain varieties, it is proposed to use several indices, among which one of the most informative and widespread is the grain yield index, which is determined by the ratio of useful products to total biomass. Batashova *et al*. (2020) proved that the index characterizes the level of attraction of useful nutrients from the leaf-stem mass to the reproductive organs and can be an indicator of the intensity of the variety and the effectiveness of cultivation technology under various agroecological conditions. According to Morgun *et al*. (2019) a prominent positive correlation of plant biomass with yield can occur at certain stages of organogenesis, which can be an additional index indicator for determining the productivity of promising varieties.

Mazur (2019) studies have found that the assessment of soybean varieties based on indices and correlations of relationships provides an opportunity to assess the productivity potential for plant biomass, yield index, and the thousand kernel weight in greater detail. The use of indices to search for valuable genotypes is widely discussed in scientific circles. Céron-Rojas & Crossa (2018) proved that the use of correlation-regression analysis of several quantitative traits helps more effectively determine the selection value of genotypes, compared to the assessment of individual indicators.

The purpose of this study was to establish the influence of sowing time and coenosis density on the correlation and regression dependences of seed yield of modern soybean varieties of different ripeness groups with yield index, biomass, and seed size in the conditions of irrigation of the Southern Steppe, to establish the optimal type of variety for unlocking the potential of productivity with unlimited cultivation technologies.

MATERIALS AND METHODS

The study was conducted according to the thematic research plan of the State Higher Educational Institution "Kherson State Agrarian and Economic University" under the task "Modern aspects of informatization of agricultural production based on modelling and forecasting of production processes in agroecosystems" (state registration number 0120U100997). Field experiments were conducted during 2019-2021 at the base of the university on the territory of the "VYKO" Farm in the Novotroitsk District of the Kherson Region in the agro-ecological zone of the Southern Steppe (HTC_{V-IX}=0.50-0.60) of the Kakhovka Irrigation System.

The soil of the experimental plot is medium loamy, dark chestnut. Agricultural techniques for growing soybean varieties in experiments were generally accepted for the southern zone of Ukraine. Predecessor – corn. The study was carried out pursuant to the methods of research on irrigated land described in the studies of Vozhehova *et al*. (2014), Ushkarenko *et al*. (2008). Statistical processing of research results was performed using the Agrostat computer software package.

In a three-factor experiment, the following were studied: sowing dates (factor A) – April 15, May 1, May 15; soybean varieties (factor B); plant density (factor C) – 500, 700, 900 thous. plants/ha. The material for the study was modern soybean varieties of Ukrainian selection of different maturity groups: fast crops – Monarkh (originator – Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences, Kherson), ArniKa (originator – NSC "Institute of Agriculture of the National Academy of Agrarian Sciences", Kyiv); early crops – Pysanka (originator V.Ya. Yuryev Institute of Plant Breeding of the National Academy of Agrarian Sciences, Kharkiv), Sofiia (originator – Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences, Kherson); mid-early crops – Sviatohor (originator – Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences, Kherson), Evridika (originator – Breeding and Genetics Institute – National Center for Seed Science and Varietal Research).

Repetition was fourfold, the sowing area of the sub-subplot – 200 m^2, the accounting area – 150 m^2. Irrigation was carried out by a VALLEY sprinkler with a pre-irrigation soil moisture level in the soil layer of 0-50 cm – 75% field capacity.

RESULTS AND DISCUSSION

A review of literature sources and studies conducted during 2019-2021 indicates that the yield value depends on the factors under study: the sowing period, the genotype of the variety, the density of coenosis. One of the indicators that depends on the genotype of the variety and the elements of the technology is the thousand kernel weight (TKW).

Over the years of research, the TKW of soybean seeds on the variants for studying the influence of the first ultra-early sowing period on April 15 averaged 156.0 g, the second sowing period on May 1 – 158.8 g, the third sowing period on May 15 – 156.4 g (Table 1).

Table 1. *TKW of soybean seeds depending on the technology elements, g (average for 2019-2021)*

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Soybean plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
April 15	Monarkh	149.9	147.7	145.3	156.0	147.6
	Arnika	145.6	143.9	140.9		143.5
	Pysanka	158.7	155.7	153.7		156.0
	Sofiia	161.6	158.7	156.7		159.0
	Svyatohor	168.7	165.7	161.3		165.4
	Evridika	167.7	164.5	160.4		164.2
Average by factor		**158.7**	**156.0**	**153.1**		
May 01	Monarkh	153.8	150.7	148.8	158.8	151.1
	Arnika	151.8	148.7	145.8		148.8
	Pysanka	162.3	159.8	155.7		159.3
	Sofiia	163.9	160.8	157.8		160.8
	Svyatohor	171.8	166.8	162.7		167.1
	Evridika	170.4	165.8	161.4		165.9
Average by factor		**162.3**	**158.8**	**155.4**		
May 15	Monarkh	148.9	146.1	144.2	156.4	146.4
	Arnika	147.7	144.9	143.8		145.5
	Pysanka	156.7	155.5	153.4		155.4
	Sofiia	159.8	157.7	155.6		157.7
	Svyatohor	170.8	169.7	161.9		167.4
	Evridika	169.8	167.5	160.8		166.0
Average by factor		**159.0**	**156.9**	**153.3**		
LSD_{05}, g		Factor A – 1.31; factor B – 2.16; factor C – 2.45				

Source: *compiled by the authors*

Therewith, the genotype of the soybean variety had the maximum effect on the TKW trait. For all sowing periods and density options, fast-growing varieties Arnika and Monarkh showed a TKW from 140.9 to 148.8 g, early crops Pysanka and Sofia – 153.4-155.6 g, mid-early crops Evridika and Sviatohor – 160.4-161.3 g, i.e., the difference between fast and mid-early crops was 12.5-19.5 g. The density of the coenosis also had a substantial impact on the TKW. In varieties of all ripeness groups, the maximum TKW was observed at a density of 500 thous. plants/ha, with an increase in density to 900 thous. plants/ha, the trait under study tended to decrease for all sowing periods.

One of the main tasks of the study was to determine the level of influence of individual elements of soybean plant productivity on the formation of real yield. There is a positive correlation of moderate strength between the TKW sign and yield (Fig. 1).

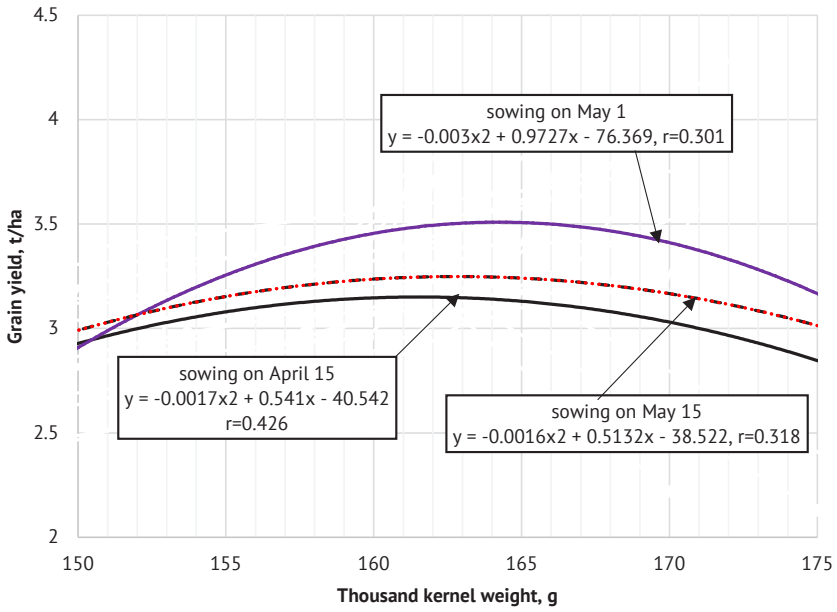

Figure 1. *Correlation and regression models of the dependence of seed yield of soybean varieties and the TKW at different sowing dates*

Source: *compiled by the authors*

Between TKW and grain yield of soybean varieties for the sowing period on April 15, the correlation coefficient was 0.426, the optimum TKW was within 161-163 g; for the sowing period of May 1, the correlation coefficient was 0.301, the optimum TKW was within 163-167 g; for the sowing period of May 15, the correlation coefficient was 0.318, the optimum TKW was within 160-165 g.

The capacity and duration of dry matter accumulation depend to an important extent on the genetic characteristics of the variety, the intensity of plant growth and the intensity of photosynthetic potential. With the intensity of growth processes, the formation of the assimilation surface of leaves accelerates, the photosynthetic activity of plants increases, and their real yield increases. The conducted studies have indicated that the formation of aboveground dry matter of modern soybean varieties largely depends on both the time of sowing and the density of plants (Table 2).

Table 2. *The mass of dry matter of soybean plants of different genotypes in the phase of bean ripening depending on the elements of agrotechnology, t/ha (average for 2019-2021)*

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
April 15	Monarkh	7.13	7.21	7.21	6.58	7.19
	Arnika	6.05	6.10	6.17		6.11
	Pysanka	6.52	6.56	6.62		6.57
	Sofiia	6.77	6.48	6.35		6.53
	Svyatohor	6.80	7.00	6.87		6.89
	Evridika	6.22	6.13	6.20		6.18
Average by factor C		**6.58**	**6.58**	**6.57**		
May 01	Monarkh	7.22	7.21	7.20	6.86	7.21
	Arnika	6.34	6.11	6.09		6.18
	Pysanka	6.60	6.30	6.42		6.44
	Sofiia	6.57	6.48	7.02		6.69
	Svyatohor	7.78	7.77	7.60		7.72
	Evridika	6.96	6.83	6.98		6.92
Average by factor C		**6.91**	**6.78**	**6.89**		

Table 2, Continued

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
May 15	Monarkh	7.07	7.07	7.11	6.75	7.08
	Arnika	6.02	6.17	5.87		6.02
	Pysanka	6.79	6.61	6.77		6.72
	Sofiia	6.93	6.79	6.93		6.88
	Svyatohor	7.49	7.20	7.27		7.32
	Evridika	6.56	6.45	6.38		6.46
Average by factor C		**6.81**	**6.72**	**6.72**		
LSD_{05}, t/ha		Factor A – 0.20; factor B – 0.31; factor C – 0.16				

Source: *calculated by the authors*

It was established that the dry matter mass of fast crops Arnika and Monarkh reached their maximum values when sowing on May 1 and a density of 500 thous. plants/ha, early crops Pysanka and Sofiia – on May 15 at a density of 500 thous. plants/ha, mid-early crops Evridika and Sviatohor – on May 1 at a density of 500 thous. plants/ha.

A positive correlation of moderate strength was observed between the dry matter mass and the yield of soybean grain (Fig. 2).

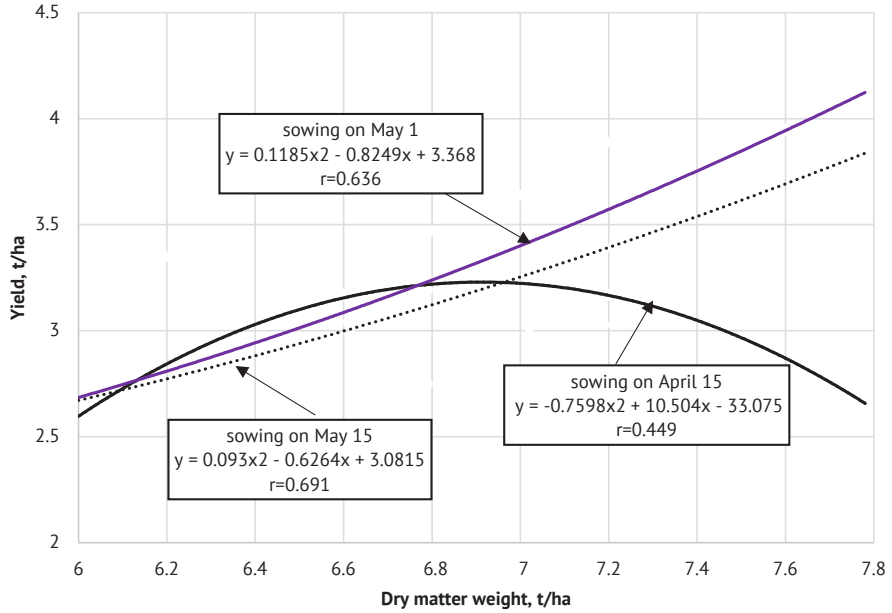

Figure 2. *Correlation and regression models of the dependence of soybean seed yield and dry matter biomass on different sowing dates*

Source: *compiled by the authors*

During the sowing period of May 01 and May 15, the correlation coefficients were of moderate strength. During the sowing period of April 15, the relationship was positive, but it had a clear curvature, which indicates a certain limited seed yield by excessive biomass.

The productivity index determines the ratio of grain mass to the total mass of the aerial part of the plant and characterizes the targeted use of assimilation products for the formation of the grain part of the crop. The indicator "yield index" of the soybean varieties under study ranged from 0.39 to 0.55 on average. This indicator of the yield index shows the physiological efficiency of the plant and its ability to convert the resulting dry matter into an economic crop (Table 3).

Table 3. *The "yield index" indicator of soybean plants of different genotypes in the bulk phase depending on the elements of agrotechnology (average for 2019-2021)*

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
April 15	Monarkh	0.40	0.42	0.43	0.46	0.42

Table 3, Continued

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
April 15	Arnika	0.39	0.40	0.42	0.46	0.40
	Pysanka	0.42	0.43	0.45		0.43
	Sofiia	0.43	0.46	0.48		0.46
	Svyatohor	0.51	0.52	0.55		0.53
	Evridika	0.50	0.53	0.54		0.52
Average by factor C		**0.44**	**0.46**	**0.48**		
May 01	Monarkh	0.45	0.47	0.44	0.48	0.45
	Arnika	0.44	0.46	0.43		0.44
	Pysanka	0.48	0.47	0.45		0.47
	Sofiia	0.49	0.48	0.44		0.47
	Svyatohor	0.55	0.53	0.52		0.53
	Evridika	0.54	0.53	0.51		0.53
Average by factor C		**0.49**	**0.49**	**0.47**		
May 15	Monarkh	0.43	0.44	0.46	0.46	0.44
	Arnika	0.41	0.42	0.45		0.43
	Pysanka	0.42	0.46	0.43		0.44
	Sofiia	0.43	0.47	0.44		0.45
	Svyatohor	0.49	0.54	0.51		0.51
	Evridika	0.50	0.53	0.52		0.52
Average by factor C		**0.45**	**0.48**	**0.47**		

Source: *calculated by the authors*

To find a relationship between the productivity indicators of soybean plants, correlation coefficients were calculated between the grain yield of soybean varieties of different origins and the yield index. The highest yield of soybeans was observed with a productivity index of 0.49 to 0.53. There is a direct dependence between these indicators of significant strength – the correlation coefficient was 0.882-0.894 (Fig. 3).

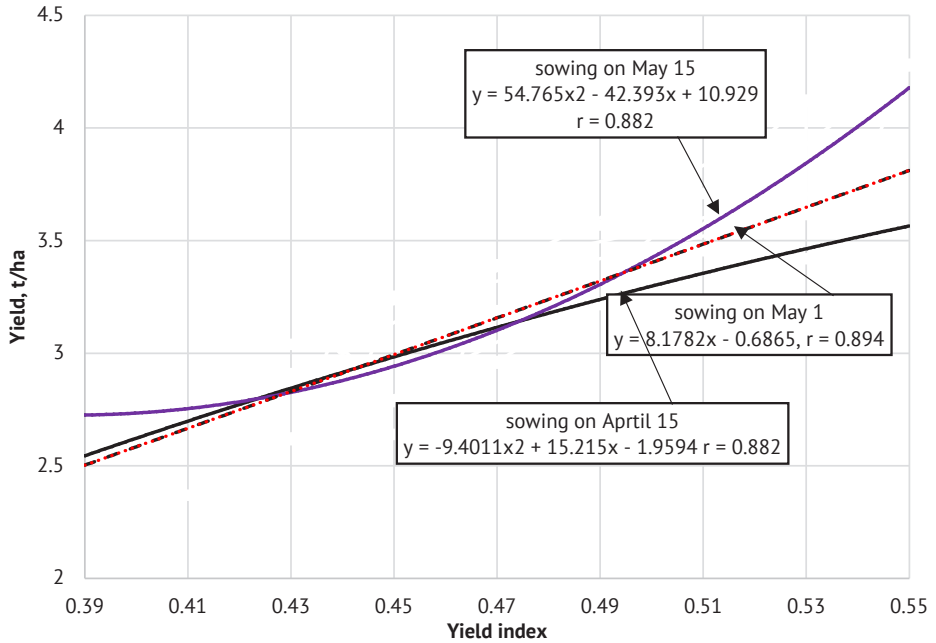

Figure 3. *Correlation and regression models of the dependence of grain yield of soybean varieties and the yield index at different sowing dates*

Source: *compiled by the authors*

The grain yield of soybean varieties of different maturation groups is the main indicator of the effectiveness of the developed elements of cultivation technology. The formation of grain yield of soybean varieties is substantially influenced by the genotype of the variety, the sowing period, and the density of plants (Table 4).

Table 4. *Yield of soybean seeds depending on the technology elements, t/ha (average for 2019-2021)*

Sowing period for soybean varieties *(factor A)*	Soy variety *(factor B)*	Plant density, thous. plants/ha *(factor C)*			Average by factor A	Average by factor B
		500	700	900		
April 15	Monarkh	2.85	3.03	3.11	3.03	3.00
	Arnika	2.36	2.44	2.59		2.46
	Pysanka	2.74	2.82	2.98		2.85
	Sofiia	2.91	2.98	3.05		2.98
	Svyatohor	3.47	3.64	3.78		3.63
	Evridika	3.11	3.25	3.35		3.24
Average by factor C		**2.91**	**3.03**	**3.14**		
May 01	Monarkh	3.25	3.39	3.17	3.30	3.27
	Arnika	2.69	2.81	2.62		2.71
	Pysanka	3.17	2.96	2.79		2.97
	Sofiia	3.22	3.11	3.02		3.12
	Svyatohor	4.28	4.12	3.95		4.12
	Evridika	3.76	3.62	3.46		3.61
Average by factor C		**3.40**	**3.34**	**3.17**		3.30
May 15	Monarkh	3.04	3.11	3.27	3.11	3.14
	Arnika	2.37	2.59	2.64		2.53
	Pysanka	2.75	3.04	2.91		2.90
	Sofiia	2.88	3.19	3.05		3.04
	Svyatohor	3.57	3.89	3.71		3.72
	Evridika	3.18	3.42	3.32		3.31
Average by factor C		**2.97**	**3.21**	**3.15**		
LSD_{05}, cm over the years of research		Factor A – 0.11; factor B – 0.15; factor C – 0.12				

***Source*:** *calculated by the authors using the program Agrostat*

It was established that the highest grain yield was formed in the mid-early crop variety Sviatohor during the sowing period of May 01 and the density of 700 thous. plants/ha – 4.28 t/ha. Fast crop varieties Arnika and Monarkh gave the highest grain yield at 2.59-3.11 t/ha with a sowing period of April 15 and a sowing density of 900 thous. plants/ha. During the sowing period on May 15, they also showed a maximum yield of 2.64-3.27 t/ha with a density of 900 thous. plants/ha. The maximum yield at 2.81-3.39 t/ha was obtained during the sowing period on May 01, the optimal sowing density was 700 thous. plants/ha.

The increase in grain yield was substantially affected by both the sowing period and the density of plants. The increase in productivity at the optimal sowing date of May 1 and a density of 700 thous. plants/ha and in comparison with the minimum productivity shown by Arnika and Monarkh varieties for sowing on May 15 and a density of 500 thous. plants/ha was 11.5-13.7%.

Sofiia and Pysanka varieties in the early crops group showed an average soybean grain yield of 2.85-3.14 t/ha over the years of research. The maximum yield of varieties of this group was shown during the sowing period on May 1 and the plant density of 700 thous. plants/ha – 3.17-3.22 t/ha. During the sowing period of April 15, the maximum yield was observed with a density of 500 thous. plants/ha – 2.98-3.05 t/ha, for sowing on May 15 and a density of 700 thous. plants/ha – 3.04-3.19 t/ha.

The increase in yield for the sowing period of May 1 and the density of 700 thous. plants/ha compared to

the minimum yield for the sowing period of April 15 and the density of 500 thous. plants/ha was 10.6-15.6%. The maximum yield in the experiment was shown by varieties of the mid-early Sviatohor and Evridika groups sown on May 01 and a density of 500 thousand plants/ha – 3.76-4.28 t/ha. Upon sowing on April 15, the maximum yield was observed at a density of 900 thous. plants/ha – 3,353.78 t/ha, upon sowing on May 15, the maximum yield of these varieties was observed at a density of 700 thous. plants/ha – 3.42-3.89 t/ha.

The yield increment during the optimal sowing period of May 1 and plant density of 500 thous. plants/ha compared to the minimum yield during the sowing period of April 15 and the density of 500 thous. plants/ha was 17.1-19.8%.

For each group of maturation of soybean varieties, the optimal sowing time and optimal plant density were determined to obtain the maximum yield under irrigation conditions. Fast varieties of crops showed the maximum yield upon sowing on May 01 and with a plant density of 700 thous. plants/ha, early and medium-early varieties of crops sown on May 01 and with a density of 500 thous. plants/ha.

Notably, the established patterns of influence of the timing and density of coenosis on the yield of innovative soybean varieties under irrigation conditions are not sufficient, and this issue requires further scientific research. According to the results of the conducted studies, a substantial increase in soybean grain yield depends on the maturation group, sowing time, and plant density. This is consistent with the data of other researchers, namely, Ivaniv & Hanzha (2021) observed that the maturity group of soybean varieties has the greatest influence on the trait "TKW", while the difference between fast and mid-early crops is 18-19 g. Plant density and TKW had a substantial impact on soybean yield under irrigation conditions. Rybalchenko (2018) established the relationship between the TKW and soybean yield at the genotypic level. The study conducted by Naydenova & Georgieva (2019) on non-irrigated lands in Bulgaria, on the contrary, shown that soybean genotypes with a shorter growing season have a higher seed yield, which may be explained by better seed filling.

In laboratory and field experiments to determine the characteristics of seed germination and growth as a function of temperature, moisture, and soil structure, Lamichhane *et al.* (2020) observed that upon sowing in mid-April, seedling death due to drought was higher, compared to earlier sowing dates. This is also confirmed by our study, when we observed certain risks of early sowing to unlock the productivity potential of varieties. Grabovsky's *et al.* (2023) showed that sowing in unheated soil can affect a decrease in field germination due to damage to seeds by fungal pathogens, which is quite consistent with our study results. Early sowing dates can also lead to changes in the habitus of soybean plants. This is confirmed by Carciochi *et al.* (2019), who found changes in morphological parameters, an increase in the number of nodes and shorter internodes. Vozhehova *et al.* (2020) observed the effect of increasing the thickening of crops from 600 to 800 thous. plants/ha on improving the photosynthetic potential, but already 900 thous. plants/ha led to a decrease in this indicator. Our research has confirmed this, but only in certain varieties. Thus, soybean varieties in the early sowing period had a sufficiently high dry matter mass at a density of 500 thous. plants/ha, but the yield was considerably higher at a density of 900 thous. plants/ha, which indicates excessive branching in the early periods and a decrease in the attraction of assimilation products to reproductive organs from lateral branches. This response to sowing dates and coenosis density is specific for individual genotypes, which should be established by field studies.

In the studies of Fellahi *et al.* (2020) superior breeding lines showed higher yield compared to control varieties due to TKW, biomass and yield index. Naydenova & Georgieva (2019) claim that among the important utilitarian characteristics of soybean varieties, the TKW is the main one that determines the productivity of the variety. This trait changes little under different growing conditions and is caused by 75-80% by the genotype of the variety and the cultivation technology, the size of seeds indirectly determines the yield. Our experiments partially confirm this, but the dependence of the yield of soybean varieties on the TKW was not linear. For each variety and sowing period, there is an optimum seed size, and this indicator is mainly regulated by plant density and varietal characteristics. In general, the present study confirms the findings of previous studies by Didora *et al.* (2022) regarding the need to improve varietal technologies to reveal the genotypic potential of soybean productivity.

Analysing the results obtained, it can be argued that the authors do not have a common opinion on the optimal timing of sowing and density of plants, so the research conducted on Ukrainian modern varieties in the conditions of the agroclimatic zone of the south of Ukraine is relevant and quite suitable for further implementation in production.

CONCLUSIONS

Based on the results of studies of the influence of technology elements on the productivity of modern soybean varieties of different maturation groups, it was found that each group of soybean maturation varieties under irrigation conditions has its own optimal sowing time and optimal cenosis density to obtain the maximum yield.

It was established that the dry matter mass depends on the density of the coenosis and the timing of sowing: fast crops Arnika and Monarkh reached their maximum values when sowing on May 1 and a density of 500 thous. plants/ha, early crops Pysanka and

Sofiia – on May 15 at a density of 500 thous. plants/ha, mid-early crops Evridika and Sviatohor – on May 1 at a density of 500 thous. plants/ha.

The maturity group of soybean varieties showed the maximum influence on the "thousand kernel weight" trait, and the mid-early crops Evridika and Sviatogor varieties showed the maximum values of the indicator – 160.4-161.3 g. In soybean varieties of all maturity groups, the maximum TKW was observed at a density of 500 thous. plants/ha, with an increase in density to 900 thous. plants/ha, the TKW decreased during all sowing periods.

Fast varieties of crops showed the maximum yield upon sowing on May 01 and with a plant density of 700 thous. plants/ha, early and medium-early varieties of crops – sown on May 01 and with a density of 500 thous. plants/ha. The maximum yield of soybean crops was observed with a yield index of 0.49 to 0.53. A significant linear relationship was established between yield indicators and the yield index (correlation coefficient was 0.882-0.894). In the experiment, the mid-early variety Sviatohor showed the highest grain yield of 4.28 t/ha for the sowing date of May 1 and a density of 700 thous. plants/ha, which is related to the genotype of the variety and optimized technology under irrigation conditions.

Therewith, additional studies are needed to determine the influence of sowing dates and plant density on the quality indicators of soybean grain, especially on protein content.

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CONFLICT OF INTEREST

None

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Сортові особливості елементів технології вирощування сої при зрошенні

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Анотація. Важливою перевагою сої (*Glycine max* (L.) Merr.) над іншими культурами є високий вміст білка та збалансованість амінокислотного складу, у зв'язку з чим актуальності набуває створення широкого набору сортів, вирощування яких змогло б забезпечити потреби переробних виробництв, а також розробка оптимальних сортових технологій вирощування, що дозволяють розкрити генотиповий потенціал продуктивності. Метою дослідження було обґрунтування особливостей формування продуктивності сучасних сортів сої залежно від елементів технології вирощування в умовах зрошення. Методи дослідження: польові, морфометричні, лабораторні, статистичні (кореляційно-регресійний аналіз). Польові дослідження проведено протягом 2019-2021 рр. в агроекологічній зоні Південного Степу в межах дії Каховської зрошувальної системи. Встановлено особливості росту і розвитку сортів сої різних груп стиглості: скоростиглих – Монарх, Арніка, ранньостиглих – Писанка, Софія, середньоранніх – Святогор, Еврідіка. Урожайність сортів сої змінювалася залежно від строків сівби, густоти рослин та сортових особливостей. Максимальна продуктивність рослин скоростиглих сортів Арніка та Монарх на рівні 2,81-3,39 т/га сформувалась за строку сівби 01 травня й оптимальної щільності посіву 700 тис. рослин/га. В ранньостиглій групі сорти Софія і Писанка максимальну урожайність 3,17-3,22 т/га показали за строку сівби 01 травня та густоти рослин 700 тис. рослин/га. Максимальну урожайність 3,76-4,28 т/га сорти середньоранньої групи Святогор, Еврідіка дали за сівби 01 травня та густоти 500 тис. рослин/га. Для отримання максимального врожаю зерна сої в умовах зрошення для кожної групи стиглості сортів існує оптимальний строк сівби й оптимальна щільність ценозу: скоростиглі сорти максимальну урожайність показали за строку сівби 01 травня та густоти 700 тис. рослин/га, ранньостиглі та середньоранні сорти – за сівби 01 травня та густоти рослин 500 тис. рослин/га. Результати дослідження можуть бути використані у виробничих умовах для коригування елементів агротехніки насінництва сої й отримання високих врожаїв з високим рівнем рентабельності

Ключові слова: строк сівби; густота рослин; урожайність; маса сухої речовини; маса 1000 насінин